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CORPS OF ENGINEERS

U. S. ARMY

DESIGN OF FLEXIBLE AIRFIELD PAVEMENTS FOR MULTIPLE-WHEEL LANDING GEAR ASSEMBLIES

REPORT NO. 1

TEST SECTION WITH LEAN CLAY SUBGRADE

TECHNICAL MEMORANDUM NO. 3-349

PREPARED BY

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

FOR

OFFICE OF THE CHIEF OF ENGINEERS

AIRFIELDS BRANCH

ENGINEERING DIVISION

MILITARY CONSTRUCTION

SEPTEMBER 1952

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PREFACE

The investigation described herein was authorized by Office, Chief of Engineers, in Instructions and Outline for Multiple Wheel Studies (Fiscal Year 1949), dated October 1948. The results presented were obtained in tests conducted between May 1949 and May 1950 by the Flexible Pavement Branch of the Waterways Experiment Station at Vicksburg, Mississippi.

Acknowledgment is made to Messrs. Gayle MacFadden, Thomas B. Pringle, and Frank Hennion of the Airfields Branch, Office, Chief of Engineers, for their assistance in planning the program. Engineers of the Waterways Experiment Station actively engaged in the direction and conduct of the program were Messrs. W. J. Turnbull, W. K. Boyd, C. R. Foster, J. M. Griffith, O. B. Ray, and S. M. Fergus.

CONTENTS

SUMMARY

The traffic tests and associated studies reported herein were performed for the purpose of developing methods for designing flexible pavements to accommodate the multiple-wheel assemblies of heavy planes.

Traffic was applied to a test section, constructed of a medium-strength lean clay, with wheel assemblies simulating those of the B-29, B-50, and B-36 planes. The B-29 assembly was loaded to 70,000 lb (35,000 lb per wheel), the B-50 assembly to 100,000 lb (50,000 lb per wheel), and the B-36 assembly to 150,000 and 200,000 lb (37,500 and 50,000 lb per wheel, respectively). Deflection measurements and other data on the behavior of the test section under traffic were obtained.

Test results indicate that multiple-wheel design criteria developed by theoretical methods from already established single-wheel curves are reasonably correct for this test section, but are slightly on the unsafe side.

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PART I: PURPOSE AND SCOPE OF THE INVESTIGATION

1. The great increase in the weights of military aircraft in the past decade has presented many new problems in the design of flexible pavements for airports. One of the most important of these problems has been to find a means of distributing the large wheel loads over the surface of the pavement. If a plane is equipped with landing gear consisting of single wheels, the load transmitted to the pavement by one wheel may, in some cases, exceed 100,000 lb. The cost, in terms of time, money, and materials, of airports to accommodate such wheel loads has become a matter of grave concern. The aircraft designers have attempted to meet this situation by developing and introducing the multiple-wheel landing gear. The B-29 and B-50 planes are equipped with a dual-wheel assembly and the B-36 plane with a dual-tandem wheel assembly. The advantages of the multiple-wheel landing gear are twofold: existing airports are enabled to accommodate heavier planes, and the strength requirements of new landing strips are greatly reduced. However, the use of multiple-wheel landing gear requires the development of new design curves for determining necessary pavement thicknesses, and the present investigation was initiated for this purpose.

2. A theoretical method of resolving the existing single-wheel

design curves into curves for multiple wheels has been developed.* This theoretical method was based to some extent on the deflections obtained with comparative single- and dual-wheel loads in the Marietta flexible pavement behavior tests, but the design curves produced by the theoretical method had not heretofore been checked by actual traffic. This report presents the results of traffic tests performed on a flexible pavement with single- and multiple-wheel assemblies to check the theoretical curves. Traffic was applied to the test section with wheel assemblies simulating those of the B-29, B-50, and B-36 planes. The B-29 assembly was loaded to 70,000 lb (35,000 lb per wheel), the B-50 assembly to 100,000 lb (50,000 lb per wheel), and the B-36 assembly to 150,000 and 200,000 lb (37,500 and 50,000 lb per wheel, respectively). This test section was constructed on a medium-strength lean-clay subgrade. Other tests are planned on other types of subgrades.

* Gayle MacFadden and others, "Development of CBR Flexible Pavement Design Method for Airfields: A Symposium," Transactions of the American Society of Civil Engineers, Vol. 115 (1950).

PART II: THE TEST SECTION AND TESTING EQUIPMENT

Test Section

Dimensions

3. The section tested with the multiple-wheel assembly, shown on plate 1, was 60 ft wide by 120 ft long and was divided into two parallel lanes each measuring 30 by 120 ft. The two lanes were constructed initially for testing with B-36 and B-29 assemblies and were designated, respectively, the B-36 lane and the B-29 lane. Later it was decided to test a B-50 assembly in the B-29 lane also. Each lane was further subdivided into three 30- by 40-ft units* of different thicknesses. The units in the B-36 lane were numbered 1, 2, and 3, and those in the B-29 (and B-50) lane were numbered 4, 5, and 6. In each lane the intermediate thickness is the design thickness indicated for the particular load and wheel spacing by the existing Corps of Engineers CBR design curves for capacity operation (5000 coverages) for multiple-wheel assemblies. The lesser and greater thicknesses, respectively, represent underdesigns and overdesigns of approximately 30 per cent in total thickness of pavement and base. The thicknesses in each unit are shown in the tabulation on the following page. A turnaround and approach area were provided at each end of the test section by extending the 3-in. asphaltic-concrete wearing course 20 ft and by placing a 3-in. layer of gravel for an additional 38 ft.

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* During the testing, the subdivisions of the testing lanes were designated "sections." Later, they were called "units" to avoid confusion with the terms "test section" and "cross section." However, it will be noted that the word "section" appears in some of the photographs.

Thickness of Units in Test Lane

Lane	Unit	Thickness, In. Wearing Course	Base Course	Total	Description
B-36	1	3	11	14	30% underdesign
	2	3	17	20	Design
	3	3	23	26	30% overdesign
B-29	4	3	7	10	30% underdesign
	5	3	12	15	Design
	6	3	17	20	30% overdesign

Construction

4. The test section was constructed within a hangar at the Waterways Experiment Station and, except for the maneuver areas at each end, it was protected from rain at all times. In the longitudinal direction the test section was constructed to a flat grade but in the transverse direction a crown of 1 per cent was provided. The side slopes, or shoulder slopes, were 1 on 15 and the end slopes were 1 on 8. Plate 1 shows details of the test section.

5. Subgrade. The subgrade was a lean clay, classification CL by the Department of the Army Unified Soil Classification System, with a liquid limit of 36 and a plasticity index of 13. The material is a brown weathered loess which occurs overlying unweathered, less plastic loess material in the vicinity of the test site. The subgrade was constructed to a density of 108 lb per cu ft and a moisture content of approximately 17.5 per cent. The average CBR value of the in-place subgrade before traffic was 18 per cent. The natural soil at the site was excavated to a depth of approximately 2.5 ft and was replaced with uniform material which had been excavated from a shallow borrow area and processed in an area outside the hangar and stored until needed. The subgrade was placed

in 7 lifts, each of approximately 5-in. compacted thickness. Each lift was reprocessed with plows and pulvimixers after placing, to assure uniformity, and was then rolled with a sheepsfoot roller loaded to give a nominal intensity of pressure of 312 psi. A total of 24 passes was applied to each lift with the sheepsfoot roller. The upper 3 in. of each lift were plowed with a spring-toothed Killifer plow behind the roller for the first 18 passes in order to prevent surface crusting. Final grading of the subgrade to the desired elevation was accomplished with scrapers and by rolling with a wobble-wheel roller. A view of the finished subgrade is shown in photograph 1. The surface of the subgrade was primed with approximately 0.8 gal per sq yd of 150 to 200 penetration asphalt cement to prevent moisture loss. The limestone base was prevented from penetrating the seal by a thin layer of fine limestone placed on the sealed subgrade.

6. Base course. The base course was constructed of a good, dense, crushed limestone from Tennessee. The material was acquired in two separate gradations and mixed off the test section. It was placed in the test section in 4-in. lifts (after compaction) using spreader boxes attached to trucks. Each lift was watered and rolled using a 3-wheel roller. The final lift was given 16 coverages with a heavily loaded rubber-tired assembly with tires inflated to 140 psi. A typical gradation curve is shown on plate 2. As constructed, the base course had a density of approximately 140 lb per cu ft, a moisture content of approximately 1.0 per cent, and a CBR generally well above 80 per cent. Before laying the wearing course, a prime coat of RC 2 was applied at the rate of 0.45 gal per sq yd.

7. Wearing course. The test section was paved with a 3-in. layer of asphaltic concrete compacted to meet laboratory specifications of 150 lb per cu ft. The aggregate, except for gradation, was the same as that used in the base course. A typical mechanical-analysis curve is shown on plate 2. An asphalt content of 4.0 per cent was selected after a study of the laboratory test results which are shown on plate 3. Control of the paving operations was established by laboratory personnel using the Marshall stability test technique. Photograph 2 shows one stage in the construction of the wearing course.

Testing Equipment

Tracking equipment

8. Tracking rig. The test traffic was applied with a specially built cart drawn by a model Super C Tournapull. The cart was so constructed that the single, dual, and dual-tandem assemblies could be mounted in the center and the weight in the load boxes at each end adjusted to produce the desired assembly load. In addition to the wheels mounted in the center of the cart for applying the test traffic, there were four other wheels in the unit. The two wheels of the towing unit were loaded to approximately 28,000 lb (14,000 lb each) and the two outrigger wheels were loaded to approximately 20,000 lb (10,000 lb each). Some coverages were unavoidably made with these additional four wheels but it is believed that their effect was minor and no account is taken of them in the analysis. Photographs 3 and 4 are two views of the load cart. Loading tests for the smaller single-wheel loads were made with an M-21 trailer shown in photograph 5.

9. Tires, wheels and loadings. The B-29 traffic was applied with 56-in., 16-ply, smooth-contour, diamond-tread tires. The B-50 and B-36 traffic was applied with 56- by 16-in., 24-ply, smooth-tread tires. Tire prints were taken before traffic to determine the inflation pressures necessary to maintain the contact areas and rolling radii at the desired values. Tire-print data are shown on plates 4, 5, and 6, and a close-up of the dual-tandem assembly is shown on photograph 6. The test section was kept clean at all times to prevent damage to the tires and wearing course. The assembly loadings and the average tire-inflation pressures and rolling radii are listed below. Tire-inflation pressures were read at frequent intervals during the traffic testing to insure that the tests were being conducted at the desired contact pressure and area.

Average Tire-inflation Pressures and Rolling Radii

Assembly Type	Assembly Load, Lb	Average Inflation Pressure, Psi	Average Rolling Radius, In.
B-29	70,000	100	24
B-50	100,000	190	24
B-36	150,000	140	24
B-36	200,000	198	24

Deflection gages

10. A deflection gage of the selsyn-motor type was installed in each of the six units of the test section. Views of the gage before and after installation are shown in photographs 7 and 8, and the location of each gage is shown on plate 7. Selsyn motors can be connected in pairs so that the movement of one actuates the other. In gages of the selsyn-motor type, this principle is used to obtain remote control of

the measuring parts of the buried gage. The operation is explained by reference to plate 8 which is a schematic drawing of the external and buried gages. With no applied load, the handcrank on the external gage is turned until the upper contact point in the buried gage touches the upper reference point. The contact of these two points closes an electronic circuit which produces both an audible and a visible signal. In this position, the Ames dial is set to zero. The handcrank is then turned until the lower contact point in the buried gage moves down and touches the lower reference point which again produces the signals. This establishes the "zero" or unloaded reading. The handcrank is then returned to the first position. The test cart is then moved into position and stopped. With the load on, the handcrank is turned until the lower contact point in the buried gage again touches the lower reference point. This gives the "load on" reading. Since the lower reference point is connected to a fixed rod anchored 20 ft below the gage, the difference of the two readings is the amount of the downward movement of the plane of reference (plane of flange at the top of the buried gage) and may be taken as the deflection. A single external gage was connected in turn to each of the six buried gages by means of a switchboard.

PART III: TESTS CONDUCTED AND RESULTS OBTAINED

Traffic and Deflection Measurements

Traffic

11. The first program of traffic in each test lane consisted of 2,000 coverages with the design loads (150,000 lb in B-36 and 70,000 lb in B-29 lane). A particular area was considered to have sustained one coverage when any tire of the assembly had passed over it. Approximate coverage of the trafficked area was accomplished by operating the test cart so that the wheels of the various wheel assemblies produced the patterns illustrated on plate 9. Although in some cases the tires did not produce complete coverages and in others they overlapped slightly, each pattern shown on plate 9 has been considered as one coverage. Effects resulting from direction of travel were minimized by reversing the direction of travel at suitable intervals. These intervals are shown in table 4.

12. The first program of traffic produced failures in the south portion of the underdesigned units (units 1 and 4) in both lanes but the majority of the test section was in good condition at the end of this program (see photographs 9 and 14). Accordingly, a second program of traffic testing was applied to the test section with heavier loads. In the B-36 lane, traffic was applied with a B-36 assembly loaded to 200,000 lb and in the B-29 lane with a B-50 assembly loaded to 100,000 lb. Except for the underdesigned units 1 and 4, both lanes withstood this additional traffic without severe failure. Unit 1 of the B-36 lane began to fail after 210 coverages and had failed completely after 610 coverages.

Unit 4 of the B-29 lane began to fail after 42 coverages of B-50 traffic and had completely failed after 328 coverages. The failure conditions in these units are shown in photographs 10, 11, 16, and 17. For convenience, the pertinent details of all test traffic are tabulated below:

Test Traffic

Lane	Assembly Type	Load on Assembly Lb	Testing Dates Beginning	Testing Dates End	Number of Coverages Applied
B-36	B-36	150,000	11 Oct 1949	28 Oct 1949	2,000
B-36	B-36	200,000	25 Apr 1950	9 May 1950	2,000*
B-29	B-29	70,000	2 Sept 1949	30 Sept 1949	2,000
B-29	B-50	100,000	7 Nov 1949	25 Nov 1949	2,000**

* Except unit 1 which failed after 610 coverages.
** Except unit 4 which failed after 328 coverages.

Deflection measurements

13. The vertical deflection, as used in this report, is the total downward movement under load both permanent and elastic. Measurements of the vertical deflection of the subgrade were made under a variety of loading conditions to obtain data for an analytical comparison of the single, dual, and dual-tandem assemblies. The loading conditions are shown in the following tabulation. The deflections measured in each case are listed in table 1. Measurements were made with the test cart positioned at various points with respect to the gage as noted in table 1. Plots of the maximum deflection versus coverage are presented on plate 10. The curves on plate 10 are labeled "adequate" and "inadequate" on the basis of behavior as analyzed from the visual observations (see paragraph 43).

Loading Conditions for Measurements of Subgrade Deflection

Type Load	Tire Inflation Pressure Psi	Spacing, In. Dual	Spacing, In. Tandem	Load Per Tire Lb	Assembly Load Lb
Single	60			5,000	5,000
Single	93			26,000	26,000
Single	122			30,000	30,000
Single	200			30,000	30,000
Single	140			38,000	38,000
Single	168			44,500	44,500
Dual	85	37.5		13,500	27,000
Dual	100	37.5		35,000	70,000
Dual	190	37.5		50,000	100,000
Dual-tandem	140	31.0	60.0	37,500	150,000
Dual-tandem	198	31.0	60.0	50,000	200,000

Deformation at gage points

14. Deformation, as used in this report, refers to the permanent downward movement produced by the test loads. The deformations of the surface of the test section and of the subgrade at the locations of the deflection gages were recorded and are presented as plots of cumulative deformation versus coverages on plates 11 and 12. The compression in the base (and to a small extent in the wearing course) is the difference between the deformation at the surface and that at the subgrade level. The deformations under the heavier loads are plotted as continuations of the curves obtained for the lighter loads. However, the coverage scales on plates 11 and 12 are reset to zero to agree with the tabulated data. The values for the deformation of the subgrade were obtained from the differences in the successive readings of the unloaded deflection gages. As shown in photograph 8, the deflection gages were installed so that the flange at the top of each gage was in the plane of the surface of the subgrade. As each load was applied and removed, the flange moved down and back. The amount by which the flange failed to recover its original

elevation was taken as the deformation of the subgrade. The values for the deformation of the surface of the test section at the points directly above each deflection gage were obtained from the cross-section data.

CBR and Pavement Tests

CBR, density, and moisture tests

15. During the period of construction, and during and after the period of traffic-testing, tests for CBR, density, and moisture content were made to insure control. These data are presented in table 2. The location of the tested areas is shown on plate 7.

Asphaltic-concrete cores

16. After construction was completed and at appropriate intervals during the traffic-testing, cores were taken from the asphaltic-concrete wearing course using a rotary coring machine. Data from testing these core samples are shown in table 3.

Cross-section Measurements and Other Observations

Cross sections

17. Cross-section measurements of the entire test section were made at 10-ft spacings and at intervals of approximately 250 coverages to record the deformation of the surface resulting from the traffic-testing. Pertinent plots of the deformation of the surface are shown on plates 13 and 14.

Trench profiles

18. In a few cases trenches were dug to determine the deformation of the surfaces of the wearing course, base course, and subgrade. Trench

profiles plotted from such data are shown on plate 15. The ordinate scale on plate 15 represents inches above or below on arbitrary datum plane. Photograph 15 shows a trench opened in unit 4.

Pavement temperature

19. Traffic was applied to the test section while the temperature of the wearing course ranged between 46 and 79 F. The temperatures were measured by inserting a thermometer into a small hole drilled in the wearing course. The thermometer bulb was approximately 2 in. below the surface. The temperatures recorded at various times during the testing are shown in tables 1 and 4.

Visual observations of the pavement surface

20. Visual observations of the surface of the test section were made throughout the traffic-testing, and the evidences of distress or failure such as cracking or rutting were carefully recorded. This material is presented in table 4 and is summarized and discussed in part IV.

PART IV: DISCUSSION AND ANALYSIS OF TEST RESULTS

21. The traffic tests and the associated studies reported herein provide data for checking the theoretical concepts now being used for developing multiple-wheel design curves from single-wheel curves. In the following paragraphs, the test data are discussed and analyzed for this purpose.

Wearing- and Base-course Behavior

22. In these studies it was the intention to confine the principal investigation to the behavior of the subgrade. For that reason, the wearing and base courses were constructed of high-quality materials to eliminate as many variables as possible. Where pavement failure occurred, it is considered that the protection afforded to the subgrade by the wearing and base courses was of inadequate thickness but not of inadequate quality. The following discussion of the wearing- and base-course behavior may not be especially pertinent to the design requirements for multiple wheels; however, the test data were obtained as a part of the tests and an analysis of them is made for the record.

Asphaltic-concrete wearing course

23. Test data from corings of the asphaltic-concrete wearing course are presented in table 3. Since wearing-course performance is considered to be determined more by the surface contact pressure than by the total load, a study was made to show the effect of tire-inflation pressures of 100 and 140 psi. For this purpose the core data shown in table 3 have been averaged as shown on the following page.

Effect of Tire Pressure on Wearing Course
(Abstracted from Table 3)

Property	Average Value 0 Coverages	Average Value after 2,000 Coverages: Tire inflation Pressure 100 Psi	Tire inflation Pressure 140 Psi
Stability (lb)	1,070	1,120	1,100
Flow (0.01 in.)	28	26	29
Unit wt total mix (lb/cu ft)	150.7	152.3	153.0
Per cent voids total mix	5.2	4.1	3.7
Per cent voids filled with asphalt	64.7	70.0	72.4

The study indicated that a general increase in the density of the wearing course occurred with coverage and that higher tire pressures produced the higher densities. The average values of the stability and flow appear to have been only slightly affected by the traffic-testing. It will also be noted from table 3 that the flow values ranged from 23 to 30 which is higher than normally considered acceptable. However, since the pavement was under the hangar and protected from the sun it was never subjected to traffic while at a high temperature. Under these conditions the high flow values are considered acceptable.

Crushed-limestone base course

24. As shown on table 2, after 2,000 coverages the base course had a CBR of 80 per cent or better except in the two underdesigned units 1 and 4. In unit 1, after 2,000 coverages with the 150,000-lb load, the base-course CBR was more than 150 per cent but it dropped to 62 per cent in the distressed area after 610 coverages with the 200,000-lb load. In unit 4, after 2,000 coverages with the 70,000-lb load, the base-course CBR had

dropped to 46 per cent in the distressed areas, and it showed a further drop to 35 per cent after 250 coverages with the 100,000-lb load. Where no distress occurred, the CBR remained consistently high.

Thickness Evaluation Based on Test Section Behavior

25. In the following paragraphs an evaluation of the test section is made with respect to the ability of each unit to withstand 2,000 coverages of the applied load. The B-36 lane, consisting of units 1, 2, and 3, is considered first, followed by the B-29 lane consisting of units 4, 5, and 6. The evaluation is based on the record of visual observations as shown in table 4 and on the CBR of the subgrade beneath the particular pavement area being considered. In each unit, the thickness referred to is the combined thickness of the wearing and base courses. The CBR values mentioned in the text are those measured in the top 2 in. of the subgrade, as it is believed that these are more pertinent than those measured at points 4 in. or more below the surface of the subgrade. The general pattern of the CBR values obtained during traffic showed that usually the CBR increased with traffic until the subgrade was overstressed after which the CBR decreased. Such a pattern makes the selection of the pertinent value for use in analysis difficult. CBR values have been selected between the initial and the maximum in each case, which are believed indicative of conditions during the period of traffic. The subgrade deflections mentioned are those measured directly beneath one wheel of the assembly which is the point at which maximum values were obtained. These and the deflections at other points are shown in table 1. In connection with the deflection measurements, it should be pointed out that they are significant only for the

area in the central portion of the unit where the single deflection gage was located (see plate 7). Installation of gages at several locations in each unit would have been desirable, especially in those units where distress was present in only a portion of the unit.

B-36 lane, 150,000-lb
load on B-36 assembly

26. Traffic-testing began on 11 October and was completed (2,000 coverages) on 28 October 1949. Pavement temperatures ranged between approximately 60 and 80 F with the major portion of the coverages applied at about 65 F.

27. Unit 1, 14-in. thickness. The deflection of the subgrade increased from 0.221 in. at the first load application to 0.253 in. at 2,000 coverages. The maximum deformation of the surface was about 1.5 in. (see plate 13) and the maximum deformation of the subgrade at the gage point was about 0.3 in. (see plate 11). Some rutting occurred before 100 coverages had been applied but was ironed out as traffic continued except in the south 7 ft of the unit between stations 0+00 and 0+07 (see plate 7). A number of small hair cracks also occurred in this portion of unit 1 after about 300 coverages and remained throughout the testing. The CBR of the subgrade in this area was 20 per cent after 510 coverages (pit 22) and 16 per cent after 1,000 coverages (pit 23). The CBR value of 20 per cent is considered pertinent to this analysis since this strength was not sufficient to prevent overstress. Because of the cracking it is considered that the area (between stations 0+00 and 0+07) was slightly inadequate. The remainder of the unit was considered adequate. The CBR of the subgrade in the adequate section was 30 per cent after 1,000 coverages (pit 24) and 34 per

cent after 2,000 coverages (pit 26). An average CBR of 32 per cent is considered pertinent to this portion of the unit. The condition of the unit at the end of testing is shown in photograph 9.

28. Unit 2, 20-in. thickness. The deflection of the subgrade under load increased from 0.156 in. at the first load application to 0.177 in. at 2,000 coverages. The maximum deformation of the surface was about 0.8 in. (see plate 13), and the maximum deformation of the subgrade at the gage point was about 0.2 in. (see plate 11). No distress was observed in this unit during the testing with the 150,000-lb B-36 load. The CBR of the subgrade after 2,000 coverages (pit 33) was 29 per cent.

29. Unit 3, 26-in. thickness. The deflection of the subgrade under load increased from 0.141 in. at the first load application to 0.154 in. at 2,000 coverages. The maximum deformation of the surface was about 1.1 in. (see plate 13) and the maximum deformation of the subgrade at the gage point was about 0.2 in. (see plate 11). No distress was observed in this unit during the testing with the 150,000-lb B-36 load. The average CBR of the subgrade after 2,000 coverages (from pit 40) was 22 per cent.

B-36 lane, 200,000-lb load on B-36 assembly

30. Traffic-testing was begun on 25 April and completed (2,000 coverages) on 9 May 1950. Pavement temperatures ranged between approximately 65 and 75 F with the major portion of the coverages applied at about 72 F. Coverages are renumbered starting at zero; however, previous traffic had some effect on the behavior.

31. Unit 1, 14-in. thickness. The deflection of the subgrade under

load increased from 0.233 in. at the first load application to 0.362 in. at 200 coverages. The maximum deformation of the surface was about 3.1 in (see plate 13) and the maximum deformation of the subgrade at the gage point was about 0.6 in. (see plate 11). Rutting and cracks resulting in failure developed in the south 10 ft of the unit between stations 0+00 and 0+10 after about 200 coverages. The entire unit was considered to have failed after 610 coverages. The failure conditions are shown in photographs 10 and 11. The CBR of the subgrade was 18 per cent after 460 coverages (pit 29) and was 13 per cent after 610 coverages (pit 30). The unit is evaluated as inadequate.

32. Unit 2, 20-in. thickness. The deflection of the subgrade under load increased from 0.214 in. at the first load application to 0.338 in. at 2,000 coverages. The maximum deformation of the surface was about 2.2 in. (see plate 13), and the maximum deformation of the subgrade at the gage point was about 0.3 in. (see plate 11). Rutting and moderately severe deformation appeared in this unit from the beginning of the 200,000-lb testing and became progressively worse. However, no cracking was observed except in the patch at pit 35. Photograph 12 shows the roughened surface and the degree of rutting which occurred in this unit after 2,000 coverages. The CBR of the subgrade was 26 per cent after 1,056 coverages (pit 35) and was 28 per cent after 2,000 coverages (average of pits 36 and 37). An average CBR of 27 per cent is considered pertinent to this portion of the unit. The unit is evaluated as borderline.

33. Unit 3, 26-in. thickness. The deflection of the subgrade under load increased from 0.195 in. at the first load application to 0.287 in. at 2,000 coverages. The maximum deformation of the surface was about

2.6 in. (see plate 13) and the maximum deformation of the subgrade at the gage point was about 0.4 in. (see plate 11). Rutting and deformation were observed in this unit from the beginning of testing with the 200,000-lb load and became progressively worse. However, no cracking was observed except in the pit-42 patch. The roughening of the surface was not as severe as in unit 2. Photograph 13 shows the condition of this unit after 2,000 coverages. The CBR of the subgrade was 19 per cent after 1,056 coverages (pit 42) and was 22 per cent after 2,000 coverages (average of pits 43 and 44). A CBR of 20 per cent is considered pertinent here, and is evaluated as adequate.

B-29 lane, 70,000-lb load on
B-29 assembly, 100-psi tire pressure

34. Traffic-testing was begun on 2 September and completed (2,000 coverages) on 30 September 1949. Pavement temperatures ranged from approximately 60 to 85 F with the major portion of the coverages applied at about 75 F.

35. Unit 4, 10-in. thickness. The deflection of the subgrade under load increased from 0.208 in. at the first load application to 0.240 in. at 2,000 coverages. The maximum deformation of the surface was about 1.0 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.3 in. (see plate 12). A few small cracks appeared around the core holes at station 0+06 almost from the beginning of the testing, and rutting was rather prominent over the entire unit. Both the cracks and the ruts ironed out with continued traffic until about 1,500 coverages had been applied; then the cracks opened to 1/16 in. and larger in the area near the south end of the section.

The CBR of the subgrade in this area after 1,500 coverages (pit 3) was 27 per cent. After 2,000 coverages only a small area in the southwest corner had actually failed but the development of ruts and cracks indicated a condition of incipient failure over the south end of the unit from stations 0+00 to 0+06. The condition of this area is shown in photographs 14 and 15. The CBR of the subgrade in this area after 2,000 coverages (pit 4) was 15 per cent. This area (6 ft at south end) is considered inadequate. The CBR value of 27 per cent at 1,500 coverages is considered pertinent for the analysis of this portion of the unit. Except for a slight deepening of ruts, no distress was observed in the remainder of the unit during the B-29 traffic. The CBR of the subgrade in this latter area after 2,000 coverages (pit 5) was 35 per cent. Evaluation of unit except for south 6 ft is borderline.

36. Unit 5, 15-in. thickness. The deflection of the subgrade under load increased from 0.150 in. at the first load application to 0.176 in. at 2,000 coverages. The maximum deformation of the surface was about 0.7 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.2 in. (see plate 12). A slight amount of rutting, which tended to iron out with the application of traffic, was the only distress observed in this unit during the B-29 testing. The CBR of the subgrade after 2,000 coverages (pit 11) was 25 per cent.

37. Unit 6, 20-in. thickness. The deflection of the subgrade under load increased from 0.127 in. at the first load application to 0.150 in. at 2,000 coverages. The maximum deformation of the surface was about 0.8 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.2 in. (see plate 12). Except for a slight amount of

rutting which ironed out with traffic, no distress was observed in this unit during the B-29 testing. The CBR of the subgrade after 2,000 coverages (pit 18) was 20 per cent.

B-29 lane, 100,000-lb load on
B-50 assembly, 190-psi tire pressure

38. Traffic-testing was begun on 7 November and was completed (2,000 coverages) on 25 November 1949. Pavement temperatures ranged from approximately 50 to 70 F with the major portion of the coverages applied at about 60 F. Coverages with the B-50 assembly are renumbered at zero but it should be remembered the previous traffic had produced certain effects.

39. Unit 4, 10-in. thickness. The deflection of the subgrade under load increased from 0.305 in. at the first load application to 0.346 in. at 66 coverages. No deflection measurements were taken in this unit after 66 coverages because the pavement was so badly broken that the gage did not function properly. The maximum deformation of the surface was about 2.1 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.7 in. (see plate 12). Cracking and rutting began in this unit almost from the beginning of the B-50 testing. As shown in photographs 16 and 17, the unit began to fail at about 42 coverages and had failed completely after 328 coverages. The CBR of the subgrade after 250 coverages (pit 7) was 11 per cent. Since failure occurred quickly, it is considered that the value of 35 per cent measured in this unit at the end of 2,000 coverages with the B-29 assembly (see paragraph 35) is more indicative of the strength that was present during the failing period than the value measured at 250 coverages. This

unit was evaluated as inadequate.

40. Unit 5, 15-in. thickness. The deflection of the subgrade under load increased from 0.205 in. at the first load application to 0.283 in. at 2,000 coverages. The maximum deformation of the surface was about 1.4 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.6 in. (see plate 12). As shown in photograph 18, cracks progressed into this unit from unit 4. Unit 5 was considered failed at this end (stations 0+40 to 0+44) after about 700 coverages. The CBR of the subgrade in this area after 750 coverages (pit 12) was 18 per cent. Inasmuch as failure progressed into this portion of unit 5 from unit 4, it is considered that an analysis from the standpoint of thickness requirements would not be valid. Except for numerous small hair cracks, no distress was observed in the remainder of this unit during the application of 2,000 coverages. The CBR of the subgrade after 750 coverages (pit 13) was 26 per cent and after 2,000 coverages (pit 14) was 23 per cent. The average, 24 per cent, is considered pertinent for this portion of the unit. Photograph 19 shows the condition of this unit after 2,000 coverages. Except for south 4 ft the unit was evaluated as borderline.

41. Unit 6, 20-in. thickness. The deflection of the subgrade under load increased from 0.188 in. at the first load application to 0.254 in. at 2,000 coverages. The maximum deformation of the surface was about 1.4 in. (see plate 14) and the maximum deformation of the subgrade at the gage point was about 0.4 in. (see plate 12). Photograph 20 shows the condition of this unit after 2,000 coverages. Except for slight hair cracks in the area around pit 18, no distress was observed in this unit during

the B-50 testing. The CBR of the subgrade after 2,000 coverages (pit 19) was 30 per cent. This unit was evaluated as adequate.

Summary

42. Adjustment of CBR data to 2,000 coverages. The CBR values for unit 1, 200,000-lb assembly load, and for unit 4, 100,000-lb assembly load, represent failure conditions for less than 2,000 coverages. These values are believed to be somewhat lower than would obtain had failure occurred at 2,000 coverages. Therefore, the CBR values for these two units have been adjusted upward in the following manner. Curves of CBR values versus coverages were developed from current flexible pavement design curves for the appropriate assembly load and thickness values as shown on plate 16. Pertinent CBR values for units 1 and 5 were then plotted at the coverage representing the failure condition and lines were drawn through the points parallel to the corresponding CBR versus coverage curves. Where these lines crossed the 2,000 coverage ordinate the adjusted CBR value was read.

43. The evaluations made in the preceding discussions and the pertinent CBR values are given in the following table. Since in all cases the degree of inadequacy varied with total thickness above the subgrade, it is considered that the distress was due to lack of sufficient thickness.

Evaluation Based on Visual Observation

Assembly Load, Lb	Unit	Thickness In.	Area Evaluated	Pertinent CBR Per Cent	Evaluation
150,000	1	14	South 7 ft of unit	20	Inadequate
			Remainder of unit	32	Adequate
	2	20	Entire unit	29	Adequate
	3	26	Entire unit	22	Adequate

Evaluation Based on Visual Observation (Continued)

Assembly Load, Lb	Unit	Thickness In.	Area Evaluated	Pertinent CBR Per Cent	Evaluation
200,000	1	14	Entire unit	25*	Inadequate
	2	20	Entire unit	27	Borderline
	3	26	Entire unit	20	Adequate
70,000	4	10	South 6 ft of unit	27	Inadequate
			Remainder of unit	35	Borderline
	5	15	Entire unit	25	Adequate
	6	20	Entire	20	Adequate
100,000	4	10	Entire unit	50*	Inadequate
	5	15	Entire unit except south 4 ft	24	Borderline
	6	20	Entire unit	30	Adequate

* Value adjusted to 2,000 coverages.

Evaluation of existing design curves

44. Plate 17 shows comparisons of the data in the preceding table and the pertinent design curves developed by theoretical resolution of the single-wheel curves. The single-wheel curves are for capacity operation. The application of 5,000 coverages in accelerated traffic tests is usually considered equivalent to capacity operation. Only 2,000 coverages were applied in these tests because in previous studies little change in behavior occurred after 2,000 coverages and the thickness requirements for 2,000 coverages are about 95 per cent of those for 5,000 coverages. This slight difference is considered in the analysis. The data from these traffic tests are plotted on plate 17 as points and the design curves are shown by solid lines. A different symbol is used to indicate the three conditions of adequate, borderline, or inadequate. This comparison indicates that the observed data and the theoretical design curves are in

fairly close agreement. The points representing adequate behavior plot below the design curve, which is proper. The points representing borderline or inadequate performance generally plot on or slightly below the design curve. For perfect agreement, these points should plot on or above the design curve; therefore, the indicated trend is that the theoretical design curves are slightly on the unsafe side. A slight additional factor on the unsafe side occurs from the fact that only 2,000 coverages were used in the test traffic. It should be noted that no account was taken of the earlier lighter traffic in the analysis of the results from the tests with the B-50 assembly and the B-36 assembly. No means of showing the effect of this earlier lighter traffic could be developed, but it is believed that it would tend to show more favorable agreement between the data and the design curves.

Thickness Evaluation Based on Deflections

Review of basic theory

45. The method by which the present design curves for multiple-wheel assemblies were developed from those for single-wheel loads has been published.* In considering the effect on the subgrade of a multiple-wheel assembly load, the method assumes that, at a shallow depth, the effect is that of the load on one wheel of the assembly whereas at a greater, or large depth, the effect is that of the total load. Between the two depths, designated as shallow and large, the effect is assumed to vary in an orderly manner. The application of this assumption to the development of

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* Gayle MacFadden and others, op. cit.

design curves for multiple-wheel assemblies can best be illustrated by a specific example. For this purpose, reference is made to plate 18 which shows how the design curves for multiple-wheel assemblies are developed from the curves for capacity operation (5,000 coverages) for single-wheel loads of the same tire-inflation pressure. This plate also includes drawings representing the tire prints and spacing dimensions of the B-29, B-50, and B-36 assemblies. It will be noted that in each case the clear space between the closest pair of tire prints is designated as "d" and the greatest center-to-center distance between any two prints as "S." As explained in the referenced article,* considerations of the theoretical stresses produced by the loads on the multiple areas show that the shallow and large depths mentioned above may be taken as "d/2" and "2S," respectively. Plate 18 indicates that for the dual wheels of the B-29 assembly, these two distances are 10.8 and 74.0 in., respectively. A design curve for a wheel load of 70,000 lb on a B-29 assembly may be found as follows: a point G is found at a thickness of 10.8 in. and a wheel load of 35,000 lb. This is the shallow depth and the single-wheel load. Another point, H is found at a thickness of 75.0 in. and a load of 70,000 lb. This is the large depth and the total assembly load. A straight line GH is drawn connecting the two points and the thickness requirements for the dual load are read at the point where this line intersects that of the proper CBR. It will be seen from this development that for a multiple-wheel assembly load, the design thickness is taken as equal to an equivalent single-wheel load which varies between the load on one wheel and the

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* Gayle MacFadden and others, op. cit.

total load on the assembly. For example, for a CBR of 6 per cent, the design thickness for a 70,000-lb load on a B-29 assembly found in this way is 30 in. which is also the design thickness for a single-wheel load of 50,000 lb. Hence it may be assumed that at a depth of 30 in. the 70,000-lb dual load has the same effect on the subgrade as a single load of 50,000 lb. This concept of an equivalent single-wheel load is used in the following discussion to evaluate the present design curves for multiple-wheel assemblies.

<u>Deflection curves for single-wheel loads</u>

46. As indicated previously, subgrade deflections were measured in each unit beneath single-wheel loads of 5,000, 26,000, 30,000, 38,000, and 44,500 lb. By assuming that the test section is an elastic body, it is possible to compute a value for the modulus of elasticity of each unit from the deflections measured in that unit. The equation used for this purpose is as follows:

$$E_m = \frac{3\ P}{2\pi w \sqrt{z^2 + r^2}}$$

E_m = modulus of elasticity in psi

P = total load in lb

w = measured subgrade deflection in in.

z = depth to the subgrade or the combined thickness of the wearing and base courses in in.

r = radius in in. of the loaded area treated as a circle.

The above expression is obtained from the formula for the deflection beneath the center of a uniform circular load at a depth "z," assuming a

value of 0.5 for Poisson's ratio*. The average values of E_m obtained in this way for each unit of the test section are as follow:

Average Values of Modulus of Elasticity

Unit	Depth z In.	Average E_m Psi
1	14	8,400
2	20	9,600
3	26	8,800
4	10	6,700
5	15	8,450
6	20	8,200

In making these computations there is no intention to represent the test section as an elastic body in the usual sense. However, these moduli when used in the formula:

$$w = \frac{3P}{2\pi E_m \sqrt{z^2 + r^2}}$$

yield curves for each unit, as shown in plates 19 and 20, which are probably the best curves that can be drawn through the test data and which also make it possible to determine for any particular contact pressure, the magnitude of the single-wheel load required to produce a given deflection. In this way, a single-wheel load can be found which will produce the same deflection as that measured beneath the multiple-wheel loads used in the tests. Curves have been computed and are shown on plates 19 and 20 for each of the units and tire pressures. The tire pressures are 140 and 198 psi, respectively, for the B-36 loads of 150,000 and 200,000 lb and 100 and 190 psi, respectively, for the B-29 and B-50 loads.

* Waterways Experiment Station TM 3-323 "Investigation of Pressures and Deflections for Flexible Pavements, Report No. 1, Homogeneous Clayey-silt Test Section," March 1951, p A18, formula 33.

Equivalent single-wheel loads

47. From the deflections shown in table 1 which were measured beneath the several assembly loads used in the traffic tests, and from the curves shown on plates 19 and 20, an equivalent single-wheel load has been determined in each case. The deflection value chosen for this study is that occurring beneath one wheel of the multiple-wheel assembly. This is the point at which the deflection was found to be greatest. The equivalent single-wheel loads obtained in this way are shown in table 5.

Evaluation of existing curves

48. Thickness requirements for loads on multiple-wheel assemblies can be obtained from the equivalent single-wheel loads described in the preceding paragraphs. This development assumes that where the maximum deflection occurring beneath a multiple-wheel assembly is equal to that occurring beneath an equivalent single-wheel load, the design requirements are the same. Values for the subgrade CBR at the point nearest the deflection gages were obtained from table 2 and used together with the values for the equivalent single-wheel load to determine the design thicknesses from CBR design curves for single-wheel loads. These data are shown in table 5 and a comparison of the thickness requirements obtained in this way with those of the present design curves is shown on plate 21. Points for the different coverages are identified. Since the single-wheel deflections were measured only at zero coverages, it is considered that the zero-coverage data are the more valid for this analysis. As in the case of the study based on test-section behavior, the comparison indicates that the theoretical design curves are slightly on the unsafe side.

PART V: CONCLUSION AND RECOMMENDATION

Conclusion

49. On the basis of the data obtained in these traffic tests on a test section on a lean-clay subgrade, it is concluded that the multiple-wheel design criteria developed from the single-wheel curves by theoretical methods are reasonably correct but are slightly on the unsafe side.

Recommendation

50. It is recommended that no changes be made in the existing design curves pending the construction and testing of a section on a weaker clay subgrade.

TABLES

Table 1

DEFLECTION DATA

TESTS IN B-36 LANE

Testing Vehicle[1]	Type Load	Load per Tire Lb	Assembly Load Lb	Tire Inflation Pressure psi	Pavement Temp.[2] F°	Location of Gage[3]	Unit 1, 14-Inch Thickness[4]: Time Load on Gage Min.	Unit 1: Average Deflec. Subgrade In.	Unit 1: Average Deformation at Gage Points In.: Subgrade	Unit 1: Surface	Unit 2, 20-Inch Thickness[4]: Time Load on Gage Min.	Unit 2: Average Deflec. Subgrade In.	Unit 2: Average Deformation at Gage Points In.: Subgrade	Unit 2: Surface	Unit 3, 26-Inch Thickness[4]: Time Load on Gage Min.	Unit 3: Average Deflec. Subgrade In.	Unit 3: Average Deformation at Gage Points In.: Subgrade	Unit 3: Surface	Coverages
								Before Traffic Tests											
a	Single	30,000	30,000	200	--	C		0.105				0.069				0.064			
				122				0.103				0.072				0.060			
		44,500	44,500	168				0.164				0.100				0.089			
		38,100	38,100	140				0.131				0.083				0.075			
		26,100	26,100	93				0.084				0.059				0.047			
e		5,000	5,000	60				0.028				0.018				0.012			
d	Dual	13,650	27,300	85	C_d			0.022				0.023				0.023			
						L		0.053				0.039				0.031			
		27,000	54,000	84		C_d		0.056				0.050				0.051			
						L		0.107				0.071				0.064			
		35,000	70,000	96-104		C_d		0.091				0.082				0.082			
				104		L		0.148	0.000			0.106	0.000			0.092	0.000		
								150,000-lb Testing											
										0.0				0.0				0.0	0
c	Dual Tandem	37,500	150,000	140	68	C_t	--	0.120	0.072		--	0.095	0.049		--	0.094	0.075		40
						RF		0.221	0.091			0.156	0.054			0.141	0.062		
										0.2				0.4				0.5	250
					64			0.241	0.138			0.173	0.100			0.141	0.096		510
										0.4				0.5				0.8	
					69			0.251	0.164			0.167	0.119			0.153	0.116		720
										0.4				0.4				0.6	750
					71			0.260	0.186	0.5		0.166	0.129	0.5		0.136	0.116	0.8	1,000
					57			0.237	0.217	0.4		0.177	0.136	0.5		0.152	0.119	0.7	1,250
					67			0.260	0.223	0.5		0.180	0.147	0.6		0.145	0.125	0.9	1,500
					--			0.248	0.238	0.6		0.177	0.153	0.7		0.165	0.131	1.0	1,750
					66			0.253	0.279			0.176	0.166			0.152	0.135		2,000
								0.249	0.286			0.178	0.166			0.155	0.134		
										0.7				0.7				0.9	

NOTES:

1. The following symbols are used for the testing vehicles:
   - a - Loading cart mounted with B-36 single tire and wheel.
   - b - Loading cart mounted with dual B-36 tires and wheels.
   - c - Loading cart mounted with dual-tandem B-36 tires and wheels.
   - d - Loading cart mounted with dual B-29 tires and wheels.
   - e - M-21 trailer.
2. The temperature of the 3-in. asphaltic-concrete wearing course was measured at a depth of approximately 2 in.
3. The following symbols are used to indicate the location of the gage:
   - C - Beneath center of single wheel.
   - C_d - Beneath centroid of dual wheels.
   - L - Beneath center of left tire of duals.
   - C_t - Beneath centroid of dual-tandem assembly.
   - C_{fd} - Beneath centroid of front dual wheels of dual-tandem assembly.
   - C_{rd} - Beneath centroid of rear dual wheels of dual-tandem assembly.
   - RF - Beneath center of right front tire of dual-tandem assembly.
   - LF - Beneath center of left front tire of dual-tandem assembly.
   - RR - Beneath center of right rear tire of dual-tandem assembly.
   - LR - Beneath center of left rear tire of dual-tandem assembly.
4. The thickness shown is the combined thickness of the wearing and base courses.

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Table 1 (Cont'd)

DEFLECTION DATA

TESTS IN B-36 LANE

Testing Vehicle[1]	Type Load	Load per Tire Lb	Assembly Load Lb	Tire Inflation Pressure psi	Pavement Temp.[2] F°	Location of Gage[3]	Unit 1 14-Inch Thickness[4] Time Load on Gage Min.	Unit 1 Average Deflec. Subgrade In.	Unit 1 Average Deformation at Gage Points In. Subgrade	Unit 1 Average Deformation at Gage Points In. Surface	Unit 2 20-Inch Thickness[4] Time Load on Gage Min.	Unit 2 Average Deflec. Subgrade In.	Unit 2 Average Deformation at Gage Points In. Subgrade	Unit 2 Average Deformation at Gage Points In. Surface	Unit 3 26-Inch Thickness[4] Time Load on Gage Min.	Unit 3 Average Deflec. Subgrade In.	Unit 3 Average Deformation at Gage Points In. Subgrade	Unit 3 Average Deformation at Gage Points In. Surface	Coverages
								200,000-lb Testing											
c	Dual Tandem	50,000	200,000	198	68	C_t	1	0.142	0.286	0.7	1	0.155	0.171	0.7	3	-0.031	0.341	0.9	0
						C_{fd}					4	0.199	0.171		4	0.000	0.341		
						RF	4	0.233	0.286		2	0.206	0.160		6	0.194	0.134		
						RR					6	0.222	0.160		3	0.196	0.134		
						C_t	3	0.180	0.262		3	0.200	0.132		3	0.186	0.132		12
						C_{fd}	4	0.282	0.262		3	0.236	0.132		3	0.202	0.132		
						RF	3	0.356	0.272		4	0.240	0.163		3	0.192	0.154		
						RR	3	0.372	0.272		3	0.254	0.163		3	0.206	0.154		
					70	C_t	2	0.136	0.384		1	0.162	0.196		2	0.186	0.168	0.7	60
						C_{fd}	3	0.240	0.384		3	0.194	0.196		3	0.200	0.168		
						RF	3	0.356	0.352		3	0.254	0.176		3	0.210	0.160		
						RR	3	0.372	0.352		2	0.256	0.176		2	0.226	0.160		
					72	C_t				0.7	2	0.168	0.238	0.7	1	0.164	0.244	1.0	200
						C_{fd}					3	0.218	0.238		3	0.176	0.246		
						LF	3	0.362	0.614		3	0.248	0.224		3	0.210	0.214		
						LR					3	0.264	0.224		3	0.248	0.214		
					72	C_t				0.9	1	0.176	0.204	0.8	1	0.206	0.286		500
						C_{fd}					2	0.224	0.204		2	0.216	0.286		
						RF		Unit 1 failed completely at 610 coverages			2	0.236	0.206		2	0.222	0.268		
						RR					2	0.260	0.206		2	0.248	0.268		
					79	C_t					1	0.170	0.280		2	0.186	0.354		1,000
						C_{fd}					2	0.228	0.280		3	0.208	0.354		
						RF					3	0.298	0.228		3	0.250	0.328		
						LF					3	0.290	0.264						
						RR					3	0.326	0.228		3	0.276	0.328		
					77	C_t						0.232	0.336	1.1	2	0.234	0.390	1.3	2,000
						C_{fd}						0.292	0.336		2	0.268	0.390		
						C_{rd}						0.318	0.336		3	0.294	0.390		
						RF						0.332	0.336		3	0.282	0.390		
						LF						0.308	0.336		3	0.266	0.390		
						RR						0.364	0.336		2	0.298	0.390		
						LR						0.348	0.336		2	0.302	0.390		

NOTES:

1. The following symbols are used for the testing vehicles:
   - a - Loading cart mounted with B-36 single tire and wheel.
   - b - Loading cart mounted with dual B-36 tires and wheels.
   - c - Loading cart mounted with dual-tandem B-36 tires and wheels.
   - d - Loading cart mounted with dual B-29 tires and wheels.
   - e - M-21 trailer.
2. The temperature of the 3-in. asphaltic-concrete wearing course was measured at a depth of approximately 2 in.
3. The following symbols are used to indicate the location of the gage:
   - C - Beneath center of single wheel.
   - C_d - Beneath centroid of dual wheels.
   - L - Beneath center of left tire of duals.
   - C_t - Beneath centroid of dual-tandem assembly.
   - C_{fd} - Beneath centroid of front dual wheels of dual-tandem assembly.
   - C_{rd} - Beneath centroid of rear dual wheels of dual-tandem assembly.
   - RF - Beneath center of right front tire of dual-tandem assembly.
   - LF - Beneath center of left front tire of dual-tandem assembly.
   - RR - Beneath center of right rear tire of dual-tandem assembly.
   - LR - Beneath center of left rear tire of dual-tandem assembly.
4. The thickness shown is the combined thickness of the wearing and base courses.

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Table 1 (Cont'd)

DEFLECTION DATA

TESTS IN B-29 LANE

Testing Vehicle[1]	Type Load	Load per Tire Lb	Assembly Load Lb	Tire Inflation Pressure psi	Pavement Temp.[2] F°	Location of Gage[3]	Unit 4 10-Inch Thickness[4] Average Deflec. Subgrade In.	Unit 4 Average Deformation at Gage Points In. Subgrade	Unit 4 Average Deformation at Gage Points In. Surface	Unit 5 15-Inch Thickness[4] Average Deflec. Subgrade In.	Unit 5 Average Deformation at Gage Points In. Subgrade	Unit 5 Average Deformation at Gage Points In. Surface	Unit 6 20-Inch Thickness[4] Average Deflec. Subgrade In.	Unit 6 Average Deformation at Gage Points In. Subgrade	Unit 6 Average Deformation at Gage Points In. Surface	Coverages
							Before Traffic Tests									
a	Single	30,000	30,000	200	--	C	0.173			0.103			0.084			
				122			0.157			0.099			0.083			
		44,500	44,500	168									0.115			
		38,100	38,100	140			0.210			0.127			0.102			
		26,100	26,100	93			0.130			0.078			0.066			
e		5,000	5,000	60			0.050			0.025			0.021			
d	Dual	13,650	27,300	85	C_d		0.022			0.019			0.023			
						L	0.083			0.049			0.040			
		27,000	54,000	84		C_d	0.047			0.053			0.055			
						L	0.147			0.096			0.079			
							B-29 Testing									
d	Dual	35,000	70,000	96-104		C_d	0.090			0.093			0.087			0
				104		L	0.208	0.000		0.150	0.000		0.127	0.000		
				96	82		0.229	0.059		0.156	0.036		0.139	0.013		72
									0.1			0.3			0.1	250
				92	79		0.210	0.092		0.160	0.061		0.149	0.031		262
									0.4			0.3			0.2	510
					70		0.249	0.134		0.169	0.089		0.141	0.045		560
					73										0.2	750
				92	77		0.243	0.202	0.3	0.186	0.112	0.3	0.149	0.064	0.2	1,030
				96	72		0.259	0.234	0.3	0.186	0.132	0.4	0.161	0.077	0.4	1,500
				110	65		0.240	0.274		0.176	0.152		0.150	0.095		2,000
									0.4			0.4			0.9	
							Special Tests -- B-36 Dual Tandem									
c	Dual Tandem	37,500	150,000	140	71	C_t	0.079			0.102			0.113			0
						RF	0.255			0.193			0.179			
							B-50 Testing									
b	Dual	50,000	100,000	184-189	52	C_d	0.154	0.270		0.163	0.141		0.156	0.090		0
				189	50	L	0.305	0.274		0.205	0.152		0.188	0.095		
				190			0.346	0.587		0.229	0.183		0.200	0.122		66
									1.8							100
					62					0.255	0.265		0.222	0.170		250
					68		Unit 4 failed at 328 coverages			0.273	0.423		0.231	0.228		500
												0.8			0.9	
					59					0.259	0.486	1.0	0.233	0.270	0.9	750
					58					0.260	0.520	1.0	0.204	0.294	1.0	1,000
					60					0.269	0.549	1.0	0.241	0.314	1.0	1,250
					56					0.275	0.559	1.1	0.239	0.324	1.0	1,500
					56					0.269	0.567	1.3	0.237	0.341	1.2	1,750
					64					0.283	0.593	1.2	0.254	0.342	1.1	2,000

NOTES:

1. The following symbols are used for the testing vehicles:
   - a - Loading cart mounted with B-36 single tire and wheel.
   - b - Loading cart mounted with dual B-36 tires and wheels.
   - c - Loading cart mounted with dual-tandem B-36 tires and wheels.
   - d - Loading cart mounted with dual B-29 tires and wheels.
   - e - M-21 trailer.
2. The temperature of the 3-in. asphaltic-concrete wearing course was measured at a depth of approximately 2 in.
3. The following symbols are used to indicate the location of the gage:
   - C - Beneath center of single wheel.
   - C_d - Beneath centroid of dual wheels.
   - L - Beneath center of left tire of duals.
   - C_t - Beneath centroid of dual-tandem assembly.
   - RF - Beneath center of right front tire of dual-tandem assembly.
4. The thickness shown is the combined thickness of the wearing and base courses.

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Table 2

SOIL TEST DATA

Unit	Thickness - In. Wearing Course	Thickness - In. Base Course	Thickness - In. Total	Test Pit No.	Base Course Average Moisture Per Cent	Base Course Average Density Lb/Cu Ft	Base Course In Place CBR Per Cent Inside Trafficked Area	Base Course In Place CBR Per Cent Outside Trafficked Area	Subgrade Average Moisture Per Cent	Subgrade Average Density Lb/Cu Ft	Subgrade In Place CBR Per Cent At Points in Top 2 In. of Subgrade Inside Trafficked Area	Subgrade In Place CBR Per Cent At Points in Top 2 In. of Subgrade Outside Trafficked Area	Subgrade In Place CBR Per Cent At Points 4 or More In. Below Surface of Subgrade Inside Trafficked Area	Subgrade In Place CBR Per Cent At Points 4 or More In. Below Surface of Subgrade Outside Trafficked Area	Coverages With B-36 Assembly Loaded To 150,000 Lb	Coverages With B-36 Assembly Loaded To 200,000 Lb	Coverages With B-29 Assembly Loaded To 70,000 Lb	Coverages With B-50 Assembly Loaded To 100,000 Lb
1	3	11	14	20					15.4	117		18			0			
				20					17.9	108				12				
				21			150+											
				22			79			114	20				510			
				22					17.6	111			11					
				23						114	16				1,000			
				23						114		24						
				23						110			17					
				23						111				16				
				23			140	136										
				24	0.8	146	147+			114	30							
				24						110			20					
				26			150+		15.4	115	34				2,000			
				26					18.2	109			15					
				27	2.1	143	120		16.8	116	22					0		
				28	1.0		119		15.9	115	37							
				29	1.1		90		16.1	116	18					460		
				30	1.2		62		15.8	117	13					610		
2	3	17	20	31					15.3	116	15				0			
				31					15.5	116		15						
				31					17.5	107				15				
				32			150+											
				33			150+		15.8	115	29				2,000			
				33					17.9	110			17					
				34	1.3	137	150+		15.6	116	30					0		
				35	1.3		150+		17.5	113	26					1,056		
				36	1.2		144		15.3	115	31					2,000		
				36					16.5	112		28						
				36					17.1	109				18				
				36					17.6	110			20					
				37	0.9		148		16.0	114	25							
				37					18.1	108			21					
3	3	23	26	38					16.6	106		21			0			
				38					16.4	114				20				
				39			122											
				40			150+		16.5	114	22				2,000			
				40					17.4	108			20					
				41	4.6	143	137+		16.0	114	25					0		
				42	1.0		90		16.4	114	19					1,056		

(Continued on next page)

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Table 2 (Cont'd)

SOIL TEST DATA

Unit	Thickness - In.: Wearing Course	Thickness - In.: Base Course	Thickness - In.: Total	Test Pit No.	Base Course: Average Moisture Per Cent	Base Course: Average Density Lb/Cu Ft	Base Course: In Place CBR Per Cent: Inside Trafficked Area	Base Course: In Place CBR Per Cent: Outside Trafficked Area	Subgrade: Average Moisture Per Cent	Subgrade: Average Density Lb/Cu Ft	Subgrade: In Place CBR Per Cent: At Points in Top 2 In. of Subgrade: Inside Trafficked Area	Subgrade: In Place CBR Per Cent: At Points in Top 2 In. of Subgrade: Outside Trafficked Area	Subgrade: In Place CBR Per Cent: At Points 4 or More In. Below Surface of Subgrade: Inside Trafficked Area	Subgrade: In Place CBR Per Cent: At Points 4 or More In. Below Surface of Subgrade: Outside Trafficked Area	Coverages: With B-36 Assembly Loaded To 150,000 Lb	Coverages: With B-36 Assembly Loaded To 200,000 Lb	Coverages: With B-29 Assembly Loaded To 70,000 Lb	Coverages: With B-50 Assembly Loaded To 100,000 Lb
3 (Cont'd)	3	23	26	43	1.3			75	16.3	113	23					2,000		
				43	1.3		84		17.3	113		19						
				43					17.9	106			14					
				43					17.9	104				15				
				44	1.0		130+		16.9	112	21							
				44					18.2	111			17					
4	3	7	10	1					16.9	109		19					0	
				1					17.5	110				15				
				2			86											
				3			61		15.9	113	27						1,500	
				3					17.3	111			19					
				4	1.3	144	46		14.5	117	15						2,000	
				4	1.1	143		70	15.7	114		28						
				4					17.0	115			13					
				4					17.1	113				21				
				5	1.2	140	76		16.0	112	35							
				5					17.0	110		22						
				6		146	92		16.1	111	35							0
				6					17.0	109			26					
				7			35		16.0	113	11							250
				7					16.7	112			14					
5	3	12	15	8					16.0	114	16						0	
				8					16.4	115		14						
				8					17.3	110				14				
				9			86											
				10			105											
				11	1.1	141	104		16.4	114	25						2,000	0
				11					18.5	104			13					
				12			96		16.3	115	18							750
				12					18.7	111			14					
				13			150+		16.4	113	26							
				13					18.5	108			16					
				14			150+		16.6	114	23							2,000
				14					19.0	110			18					
6	3	17	20	15					17.0	111		18					0	
				15					17.6	107				13				
				16			71											
				17			128											
				18		137	142+		17.2	111	20						2,000	0
				18					17.8	112			19					
				19			150+		17.2	111	30							2,000
				19					17.9	109			16					

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Table 3

TESTS OF PAVEMENT CORES

Unit	Coverage	Marshall Stability Lbs	Flow Value Units of 1/100 Inch	Unit Weight Lbs Per Cu Ft: Total Mix	Unit Weight Lbs Per Cu Ft: Aggregate Only	Voids Per Cent: Total Mix	Voids Per Cent: Aggregate Only	Voids Per Cent: Filled With Asphalt
			B-36 Traffic - Assembly Load of 150,000 Lb					
1	0	868	23	150.4	144.4	5.3	14.8	64.2
	500	---	--	153.1	147.0	3.7	13.4	72.4
	2000	1056	28	152.6	146.5	3.9	13.6	71.3
2	0	837	26	151.4	145.3	4.7	14.3	67.1
	500	1266	30	153.1	147.0	3.6	13.3	72.9
	2000	1178	30	153.4	147.3	3.4	13.1	74.0
3	0	453	30	151.3	145.2	4.8	14.4	66.7
	500	1342	30	152.8	146.7	3.8	13.5	71.9
	2000	1060	30	152.9	146.8	3.8	13.5	71.9
			B-29 Traffic - Assembly Load of 70,000 Lb					
4	0	1196	30	149.8	143.8	5.7	15.2	62.5
	1500	1380	26	152.9	146.8	3.8	13.5	71.9
	2000	1214	26	151.9	145.8	4.4	14.0	68.6
5	0	1530	30	149.9	143.9	5.6	15.1	62.9
	2000	1064	24	152.0	145.9	4.3	13.9	69.1
6	0	1521	30	150.6	144.6	5.2	14.8	64.9
	2000	1076	28	153.0	146.9	3.7	13.4	72.4

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Table 4

TRAFFIC OBSERVATIONS

Unit 1

Pavement Temperature	Coverages	Traffic Observations
		150,000-lb load
78°	20	Slight amount of rutting noticeable
68°	60	Rutting noticeable at Sta 0+05
72°	100	Rutting appears to be ironing out
70°	250*	No change
66°	320	Slight amount of cracking noticed from Sta 0+00 to 0+05
64°	510	CBR Pit 22 opened and tested
66°	510*	No change
	511	Cracks appear around CBR Pit 22 patch
61°	750*	No change
	800	Large amount of movement and cracking appearing from Sta 0+00 to 0+10
70°	1,000*	Sealing up of cracks from Sta 0+00 to 0+10 - CBR Pits 23, 24, and 25 opened and tested
67°	1,250*	Small cracks progressing from Sta 0+00 to 0+10
64°	1,500*	No change
63°	1,688	Small hair cracks opening and closing at Sta 0+04, varying with traffic movement
66°	1,750*	No change
	2,000	CBR Pit 26 opened for after-traffic tests -- end of test with 150,000-lb load
		200,000-lb load
	0	Pits 27 and 28 opened for "before-traffic" tests
70°	24	Rutting from Sta 0+00 to 0+30 -- the cracks around pits not progressing
	108	Cracks progressing from all pit patches -- a large amount of deformation noticeable throughout unit
72°	200*	No change
	210**	Unit considered to have failed between Sta 0+00 and 0+08 -- traffic continued on remainder of unit
72°	266	Considerable rutting throughout unit
	460	CBR Pit 29 opened and tested -- CBR patch cracked when traffic resumed
64°	610	Cracks around all pit patches progressing rapidly -- CBR Pit 30 opened and tested -- unit considered failed at 610 coverages

Unit 2

Pavement Temperature	Coverages	Traffic Observations
		150,000-lb load
78°	20	Slight amount of rutting noticeable
72°	100	Rutting appears to be ironing out
70°	250*	No change
66°	510*	No change
61°	750*	No change
70°	1,000*	No change
67°	1,250*	No change
64°	1,500*	No change
66°	1,750*	No change
	2,000	CBR Pit 33 opened for after-traffic tests -- end of test with 150,000-lb load
		200,000-lb load
	0	Pit 34 opened for "before-traffic" tests
72°	200*	No change
76°	506	Slight signs of rutting noted and area around Pit 34 depressed slightly
	1,056	CBR Pit 35 opened and tested
74°	1,366	Consolidation of CBR Pit 35 patch so bad that patch is repaired with cold mix -- surrounding pavement showing considerable deformation
72°	1,650*	From Sta 0+60 to 0+80 deflection is noticeable under traffic but no change in area around Pit 35 noticeable
73°	2,000	CBR Pits 36 and 37 opened and tested -- from Sta 0+60 to 0+80 the surface is badly deformed but no cracking is visible in unit except around Pit 35 patch -- end of test with 200,000-lb load

Unit 3

Pavement Temperature	Coverages	Traffic Observations
		150,000-lb load
78°	20	Slight amount of rutting noticeable
68°	60	Rutting appears to be ironing out
70°	250*	No change
66°	510*	No change
61°	750*	No change
70°	1,000*	No change
67°	1,250*	No change
64°	1,500*	No change
66°	1,750*	No change
	2,000	CBR Pit 40 opened for after-traffic tests -- end of test with 150,000-lb load
		200,000-lb load
	0	Pit 41 opened for "before-traffic" tests
72°	200*	No change
76°	506*	Slight signs of rutting noted
	1,056	CBR Pit 42 opened and tested
74°	1,366	Consolidation of CBR Pit 42 patch so bad that patch is repaired with cold mix -- surrounding pavement showing considerable deformation
72°	1,650*	Deflection noticed from Sta 1+00 to 1+20
73°	2,000	CBR Pits 43 and 44 opened and tested -- from Sta 1+00 to 1+20 the surface is badly deformed but no cracking is visible in unit except around Pit 42 patch -- end of test with 200,000-lb load

* Indicates direction of traffic reversed.
** After 210th coverage, number of coverages in Unit 1 does not coincide with number in Units 2 and 3.

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Table 4 (Cont'd)

Unit 4

Pavement Temperature	Coverages	Traffic Observations
		70,000-lb load -- B-29 Assembly
80°	28	Slight rutting caused by "before-traffic" loading tests is ironing out
82°	68	Some rutting appears
78°	136	Ruts are smoothing out
79°	150	Cracks appearing at core holes at Sta 0+06
80°	240	Rutting more pronounced
85°	280	Increase in cracking at core holes at Sta 0+06
73°	368	Ruts from Sta 0+00 to 0+20 approach breaking point
76°	442	Conspicuous surface deflection measured and found to be 0.15"
80°	498	Slight cracking occurs from Sta 0+00 to 0+06
70°	510*	Ruts smoothing out after reversal of traffic
	650	Smoothing out of ruts continues
73°	750*	No change
73°	844	Slight cracking between Sta 0+00 and 0+06 reappears
78°	1,030*	Cracks from Sta 0+00 to 0+06 reappearing
70°	1,110	Cracks from Sta 0+00 to 0+06 reappearing and disappearing
72°	1,210	Only a few cracks noticeable at Sta 0+00
76°	1,250	Crack 1/16" wide appearing and disappearing from Sta 0+00 to 0+05
72°	1,400	Cracks and ruts again noticeable from Sta 0+00 to 0+05
60°	1,500*	CBR Pit 3 opened and tested
67°	1,516	Cracks appear around patched Pit 3
73°	1,540	All bond is broken in Pit 3
75°	1,564	Cracks running across Pit 3
66°	1,684	Hair cracks increasing around Pit 3
	1,732	Additional hair cracks around Pit 3
75°	1,750*	More small cracks appear
63°	1,783	Cracks 1/4" wide appear near Pit 3 - patch shows excessive movement - ruts are deeper
62°	2,000	CBR Pits 4 and 5 opened for "after-traffic" tests - small cracks still around Pit 3 - end of test with B-29 load
		100,000-lb load -- B-50 Assembly
	0	CBR Pit 6 opened for "before-(B-50)-traffic" tests
62°	16	All patches in unit broken around edge of Pit 6
62°	20	Patch at Pit 3 broken and cracks spreading
	42	End of unit between Sta 0+00 and 0+15 declared failed because of large ruts and broken pavement - traffic continued on remainder of unit
	70	Cracks 1/4" wide progress to Sta 0+20
	80	Small cracks noticeable throughout unit
	100	Unit declared failed up to Sta 0+25 - traffic continued on remaining portion of unit
52°	150*	No change
	200	Hair cracks between Sta 0+25 and 0+40 increasing
	250	CBR Pit 7 opened and tested
	328	Entire unit declared failed - M-6 landing mat placed over area between Sta 0+30 and 0+40 to retard migration of cracks from unit 4 to unit 5

Unit 5

Pavement Temperature	Coverages	Traffic Observations
		70,000-lb load -- B-29 Assembly
80°	28	Slight rutting caused by "before-traffic" tests is ironing out
85°	262	Slight increase in deflection noticeable
79°	430	Small amount of rutting
70°	510*	No change
	650	Smoothing out of ruts continues
73°	750*	No noticeable change
78°	1,030*	Slight amount of deflection noticeable over entire unit
76°	1,250*	No change
60°	1,500*	No change
75°	1,750*	No change
62°	2,000	CBR Pit 11 opened for "after-traffic" tests -- end of test with B-29 load
		100,000-lb load -- B-50 Assembly
62°	44	All bond broken between pavement and CBR Pit 11 patches but no visible cracks
52°	150*	No change
56°	264	Find hair cracks working out from CBR Pit 11 patch
67°	470	Cracks from Sta 0+40 to 0+55
60°	646	Cracks spreading rapidly between Sta 0+40 and 0+46
68°	700	First 4 ft of unit, from Sta 0+40 to 0+44, considered to have failed
57°	750	CBR Pits 12 and 13 opened and tested
54°	750*	Mat placed on unit from Sta 0+40 to 0+55 due to failure of unit from Sta 0+40 to 0+46
66°	790	Small hair cracks at Sta 0+58
64°	850	Small hair cracks throughout unit
59°	1,146	Small crack near Test Pit 13 about a foot in length
51°	1,396	Hair cracks running laterally across unit at Sta 0+58
	1,500*	No change
46°	1,632	Hair cracks opening and closing, varying with lateral traffic
51°	1,750*	No change
66°	1,952	Small hair cracks beginning to run laterally between Sta 0+70 and 0+80
	2,000	CBR Pit 14 opened for after-traffic tests - end of test with B-50 load

Unit 6

Pavement Temperature	Coverages	Traffic Observations
		70,000-lb load -- B-29 Assembly
80°	28	Slight rutting caused by "before-traffic" tests is ironing out
85°	262	Slight increase in deflection
70°	510*	No change
	650	Smoothing out of ruts continues
73°	750*	No change
78°	1,030*	Slight amount of deflection over entire unit
76°	1,250*	No change
60°	1,500*	No change
75°	1,750*	No change
62°	2,000	CBR Pit 18 opened for "after-traffic" tests - end of test with B-29 load
		100,000-lb load -- B-50 Assembly
62°	50	Tiny cracks showing up around CBR Pit 18 patch
52°	150*	No change
54°	750*	No change
59°	1,230	No cracks visible
51°	1,500*	No change
51°	1,750*	No cracks visible
60°	1,832	First spreading of cracks noticeable around Pit 18 patch
	2,000	CBR Pit 19 opened for after-traffic tests - end of test with B-50 load

* Indicates direction of traffic reversed.

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Table 5

DESIGN THICKNESS FOR EQUIVALENT SINGLE-WHEEL LOADS

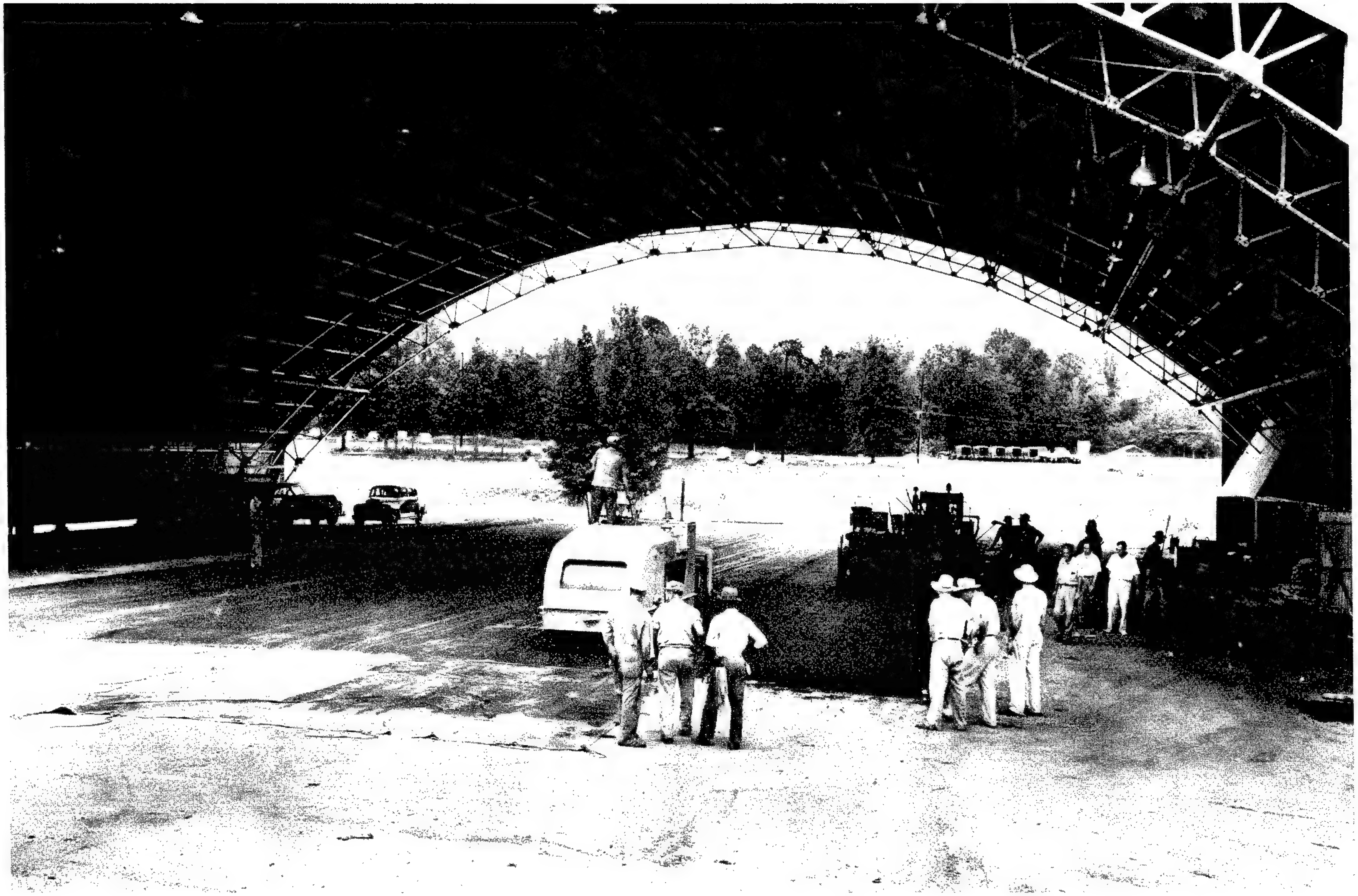
Unit	Assembly Load Lb	Tire Inflation Pressure Psi	Maximum Measured Deflection In.	Number of Coverages	Equivalent Single-wheel Load Lb[1]	CBR near Gage Per Cent	Design Thickness, In.[2]
1	150,000	140	0.221	40	75,000	18	19
			0.260	1,000	93,000	30	15
			0.253	2,000	88,000	34	13
2	150,000	140	0.156	40	75,000	15	21
			0.178	2,000	88,000	29	15
3	150,000	140	0.141	40	75,000	21	17
			0.155	2,000	83,000	22	17
1	200,000	198	0.233	0	73,000	22	18
			0.362	200	128,000	20	25
2	200,000	198	0.222	0	103,000	30	18
			0.326	1,000	157,000	26	25
			0.364	2,000	178,000	31	25
3	200,000	198	0.196	0	104,000	25	20
			0.276	1,000	147,000	19	28
			0.302	2,000	162,000	23	26
4	70,000	96-104	0.208	0	46,500	17	14
		96	0.259	1,500	64,000	27	12
		110	0.240	2,000	57,000	35	9
5	70,000	96-104	0.150	0	52,500	15	17
		110	0.176	2,000	64,000	25	12
6	70,000	96-104	0.127	0	52,500	18	14
		110	0.150	2,000	63,000	20	15
4	100,000	184-189	0.305	0	61,000	35	11
5	100,000	184-189	0.205	0	67,000	25	15
		190	0.259	750	89,000	18	21
			0.283	2,000	99,000	23	20
6	100,000	184-189	0.188	0	75,000	20	19
		190	0.254	2,000	105,000	30	19
4	150,000	140	0.255	0	55,000	35	10
5	150,000	140	0.193	0	68,000	25	15
6	150,000	140	0.179	0	75,000	20	17

[1] The equivalent single-wheel load is defined as the single-wheel load which would produce the same deflection as that measured beneath the load on the multiple-wheeled assembly.

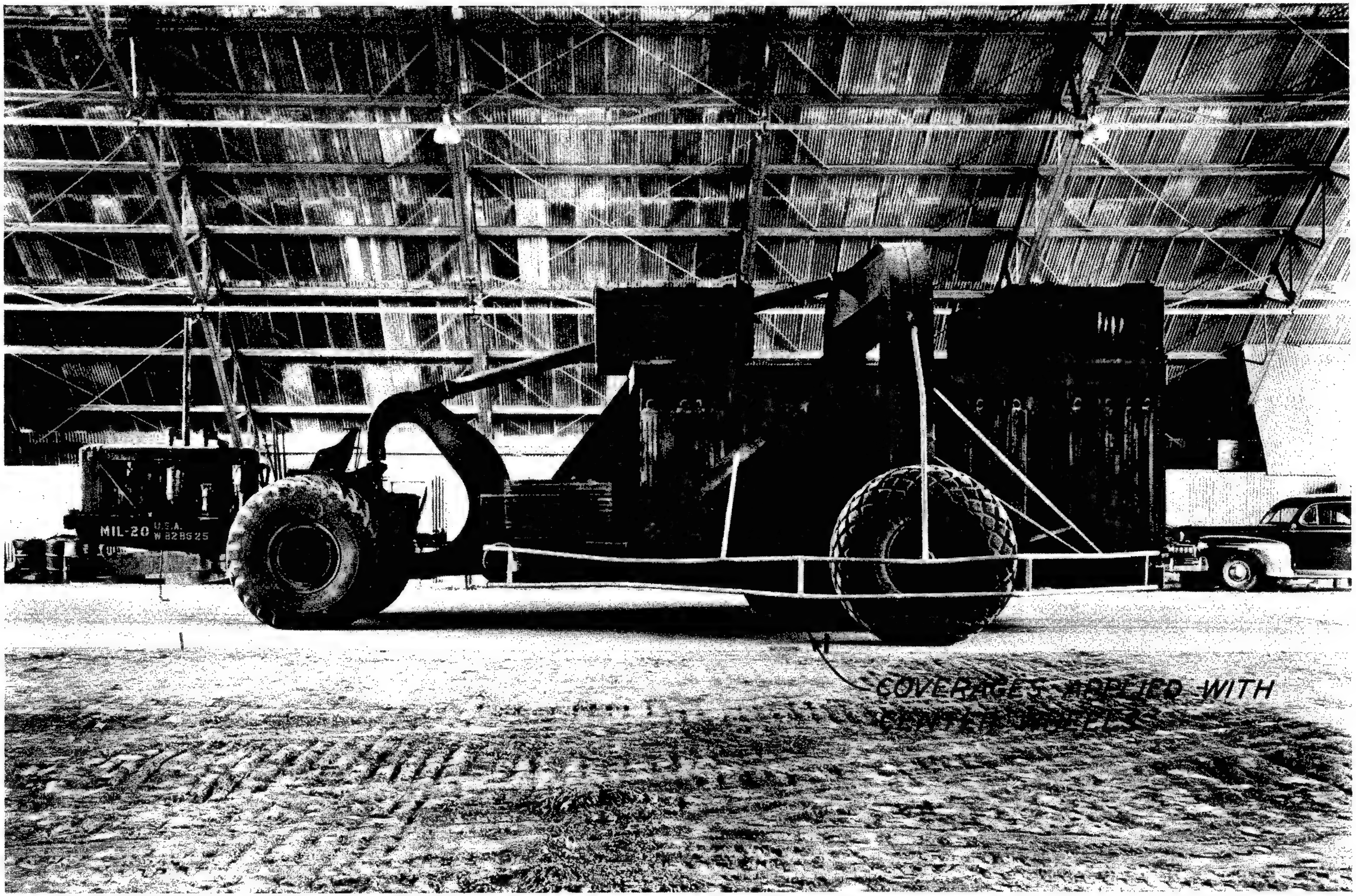
[2] Based on the CBR and the equivalent single-wheel load.

PHOTOGRAPHS

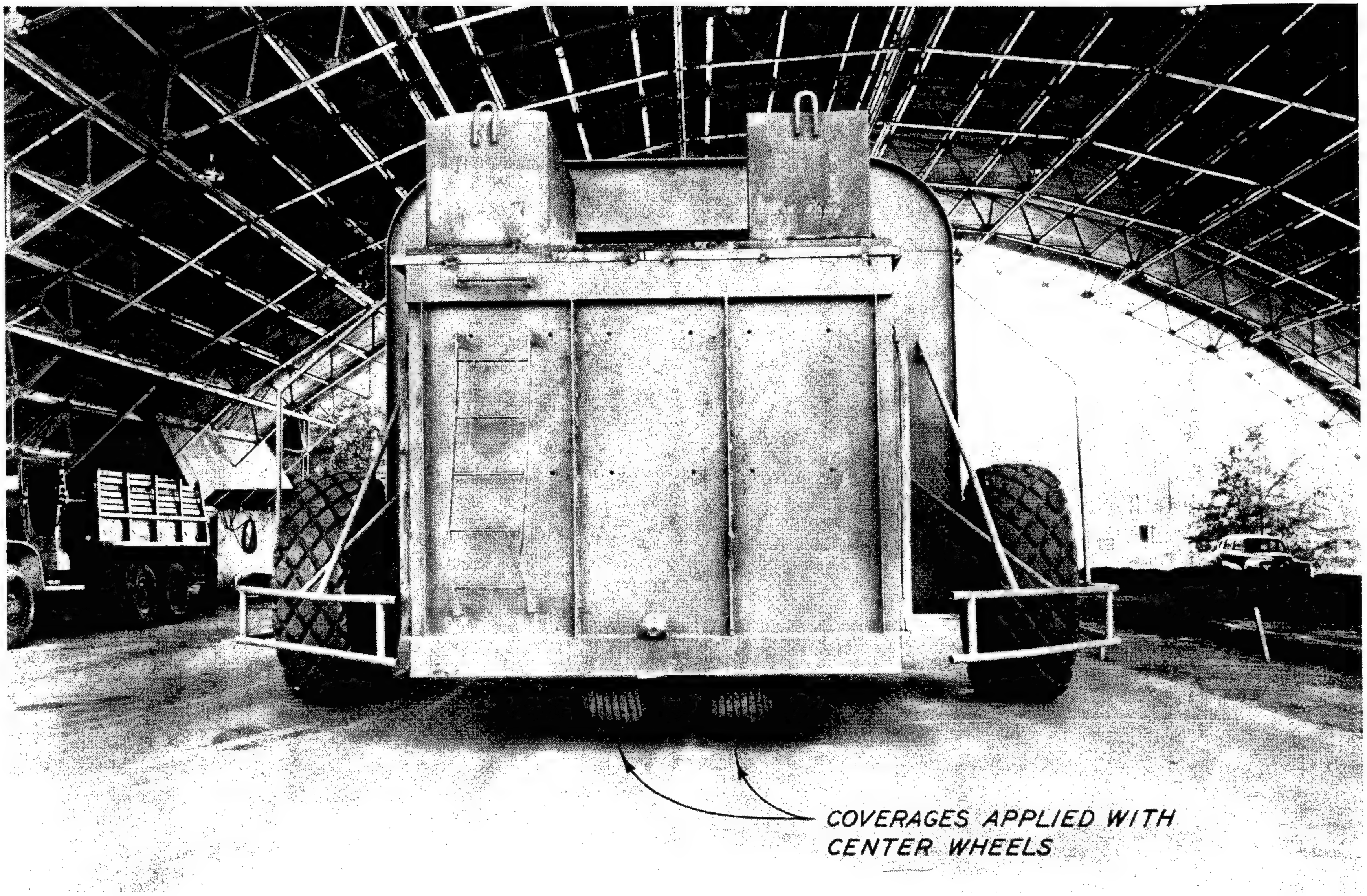
Photograph 1. View of subgrade before placing base



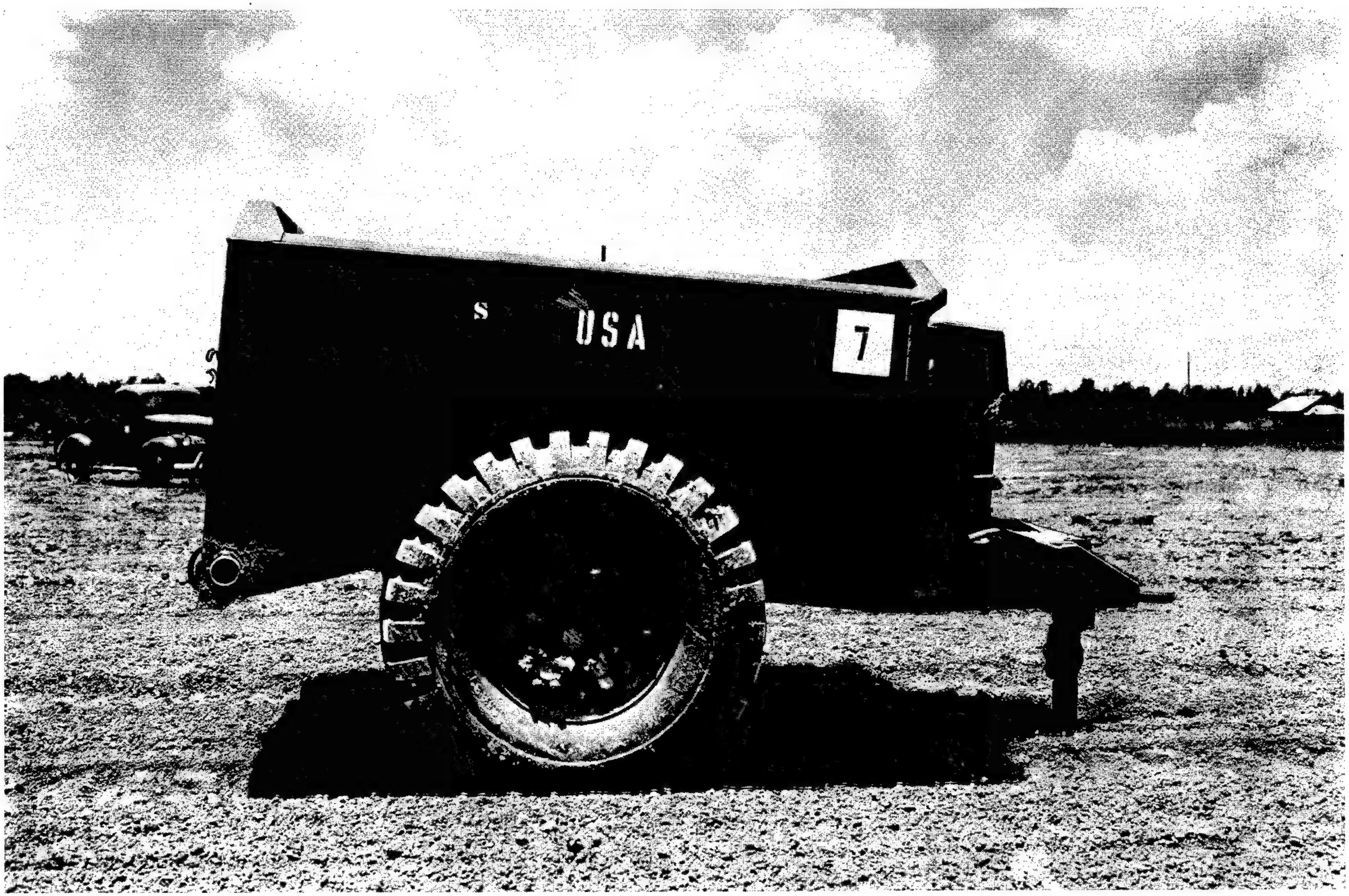
Photograph 2. Over-all view of test section showing paving operations



Photograph 3. Load cart and Super C Tournapull used for traffic tests



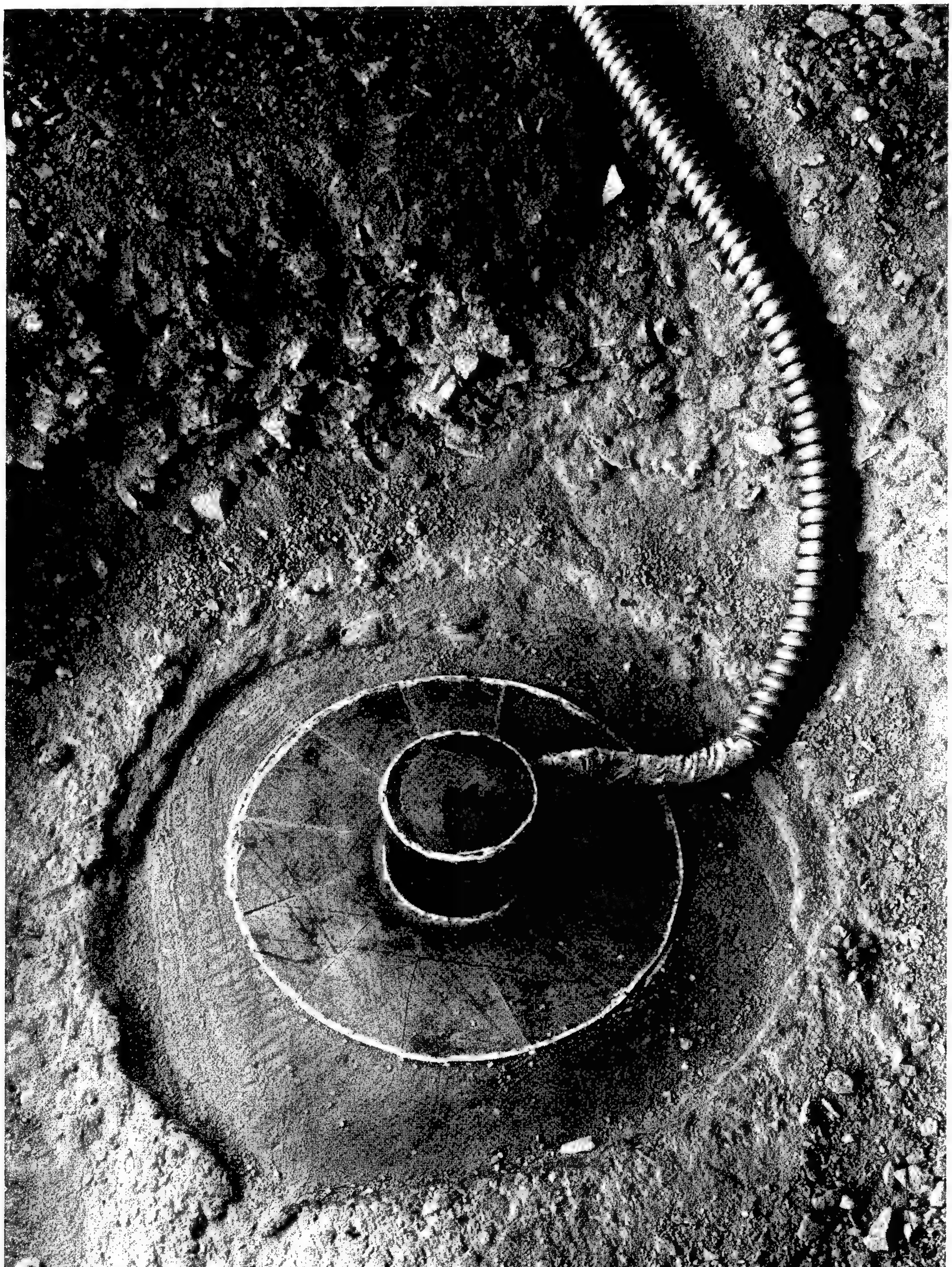
Photograph 4. Rear view showing center wheels loaded to 200,000 lb and outrigger wheels



Photograph 5. M21 ammunition trailer

Photograph 6. Close-up of B-36 assembly loaded to 200,000 lb

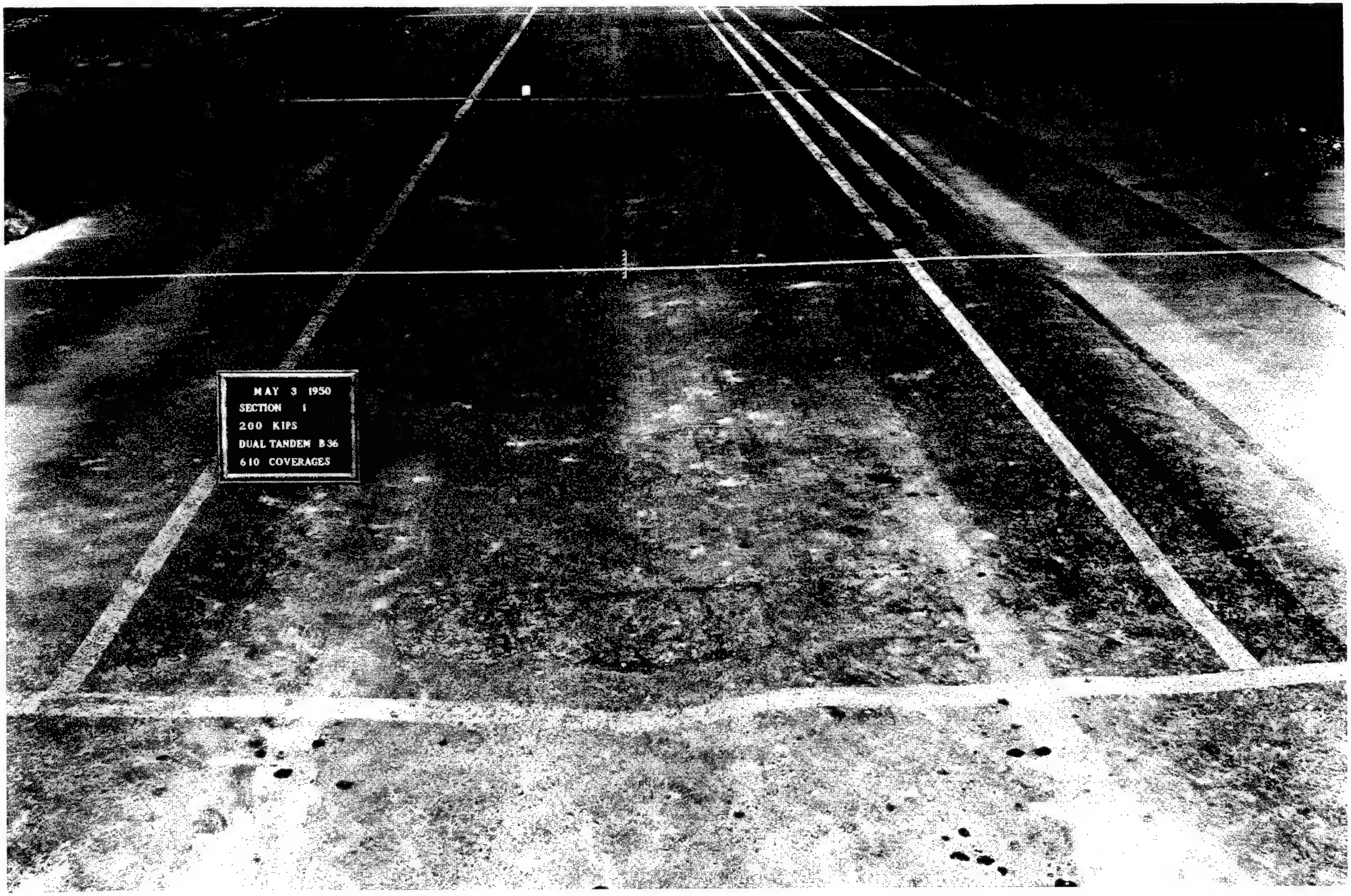
Photograph 7. View of selsyn-motor type deflection gage used in tests



Photograph 8. View of deflection gage installed in unit 5

Photograph 9. Unit 1, 14-in. thickness. View showing rutting after 2,000 coverages with 150,000-lb load on B-36 assembly

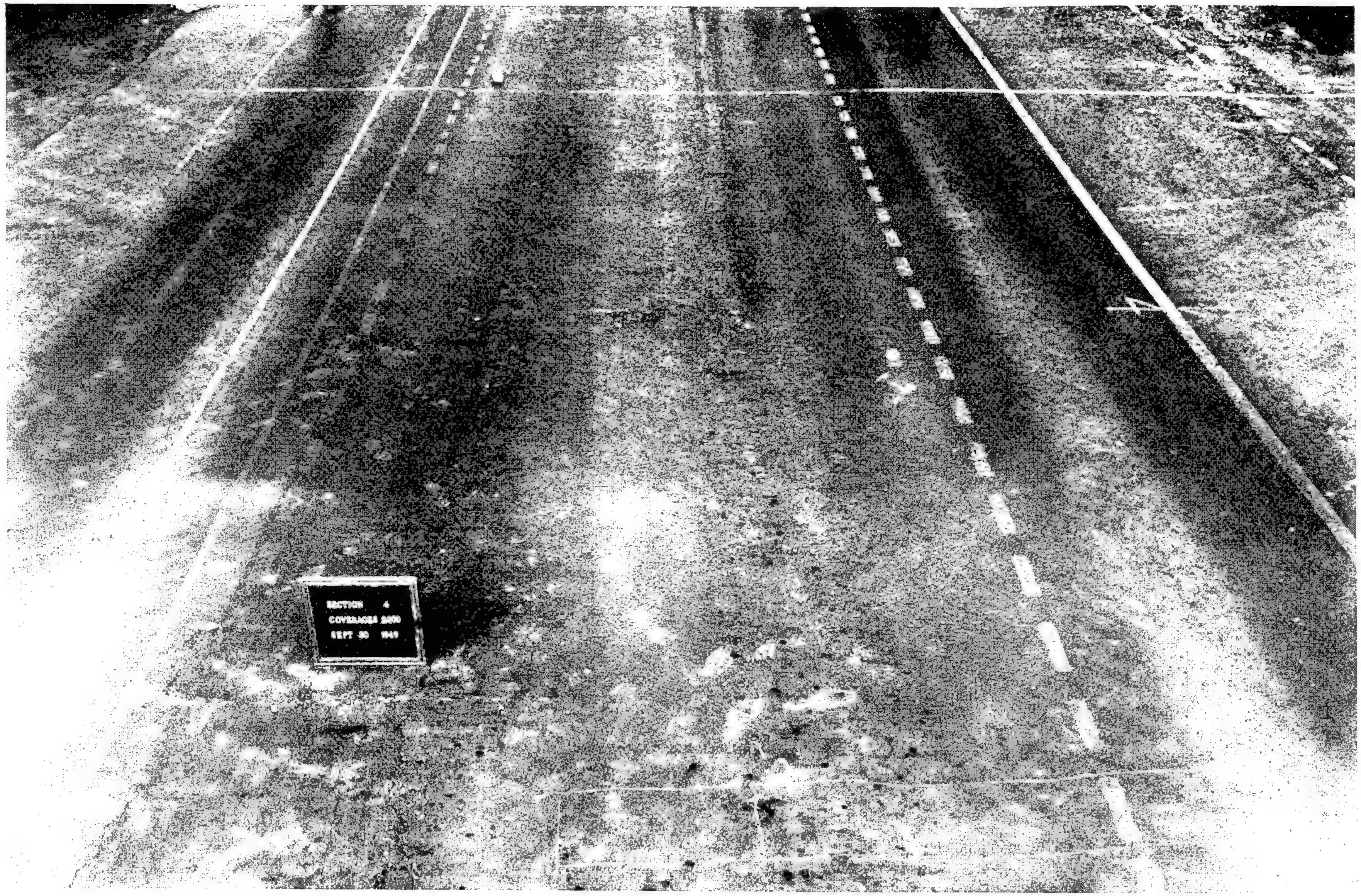
Photograph 10. Unit 1, 14-in. thickness. View showing rutting and failure after 200 coverages with 200,000-lb load on B-36 assembly



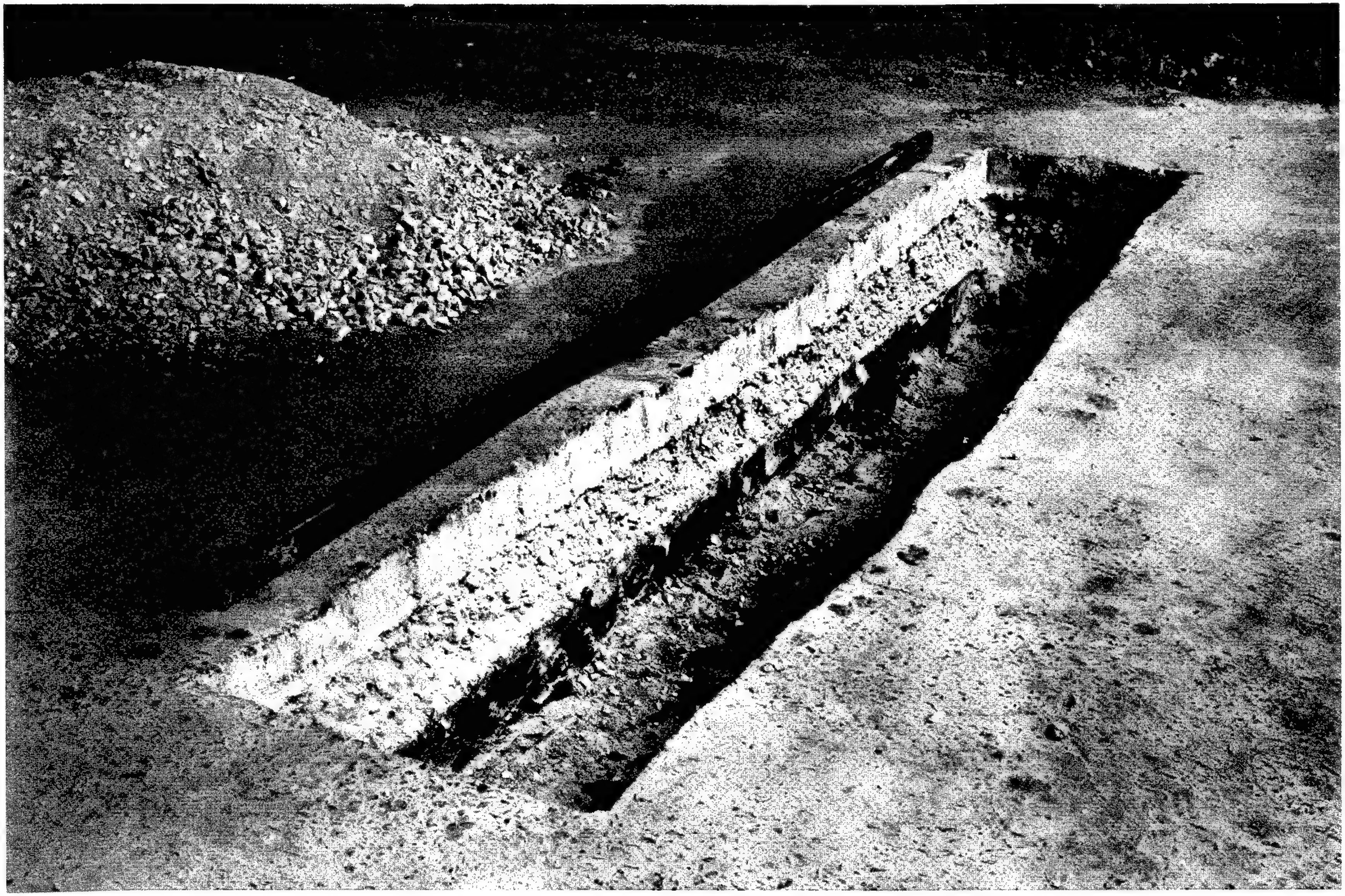
Photograph 11. Unit 1, 14-in. thickness. View after 610 coverages with 200,000-lb load on B-36 assembly

Photograph 12. Unit 2, 20-in. thickness. View showing rutting after 2,000 coverages with 200,000-lb load on B-36 assembly

Photograph 13. Unit 3, 26-in. thickness. View after 2,000 coverages with 200,000-lb load on B-36 assembly

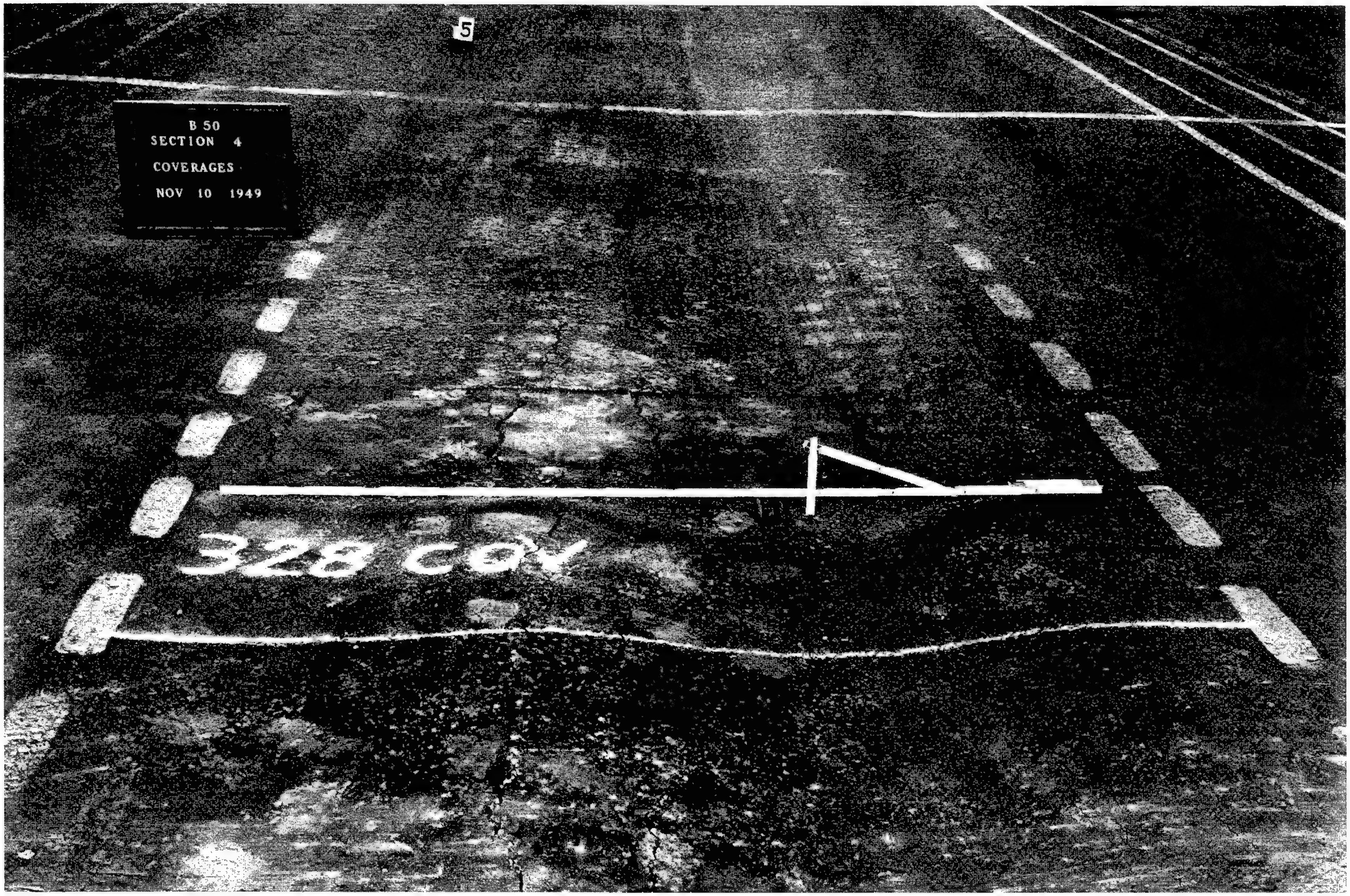


Photograph 14. Unit 4, 10-in. thickness. View showing cracks after 2,000 coverages with 70,000-lb load on B-29 assembly

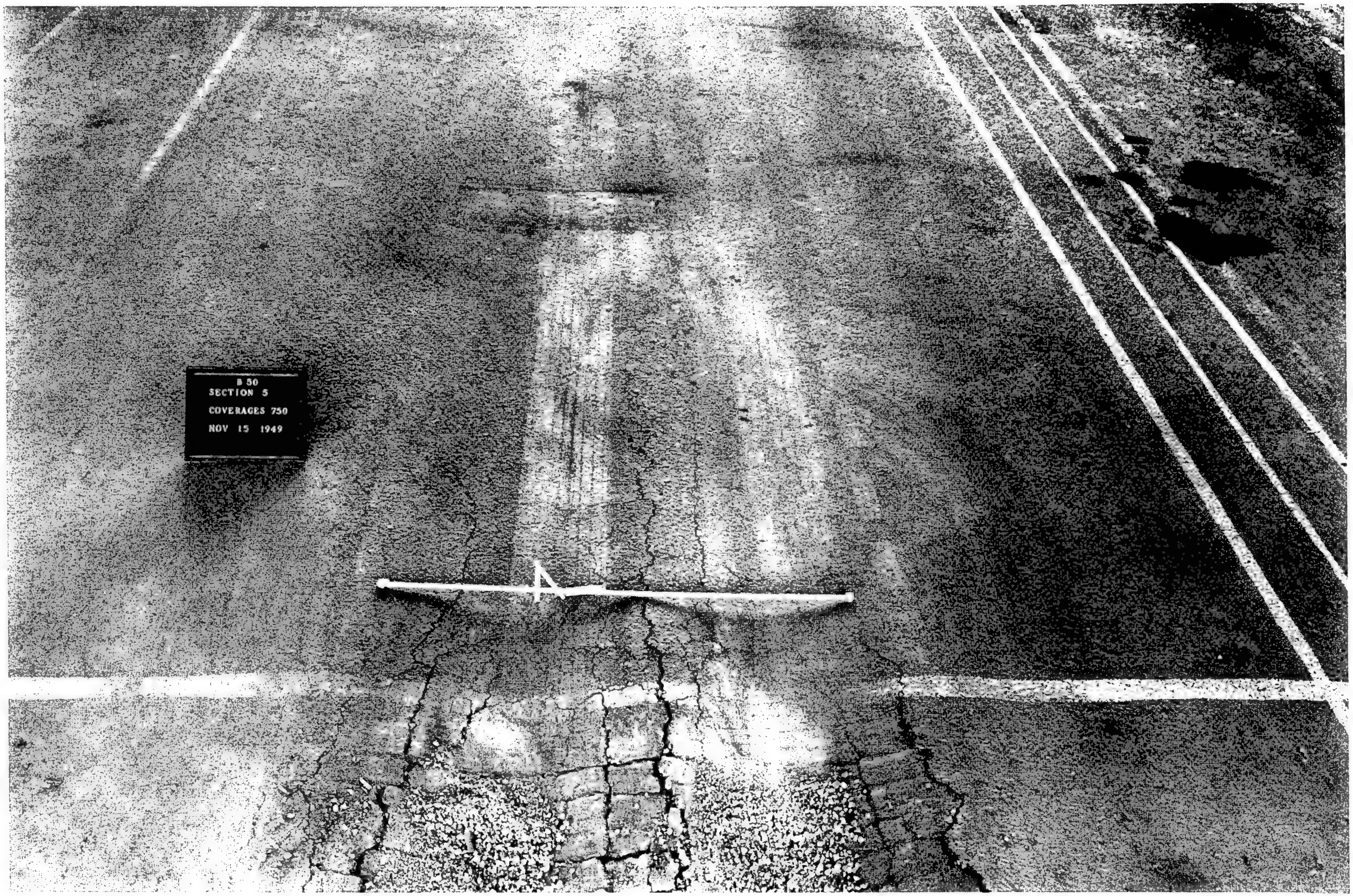


Photograph 15. Unit 4, 10-in. thickness. View of pit 4 after 2,000 coverages with 70,000-lb load on B-29 assembly

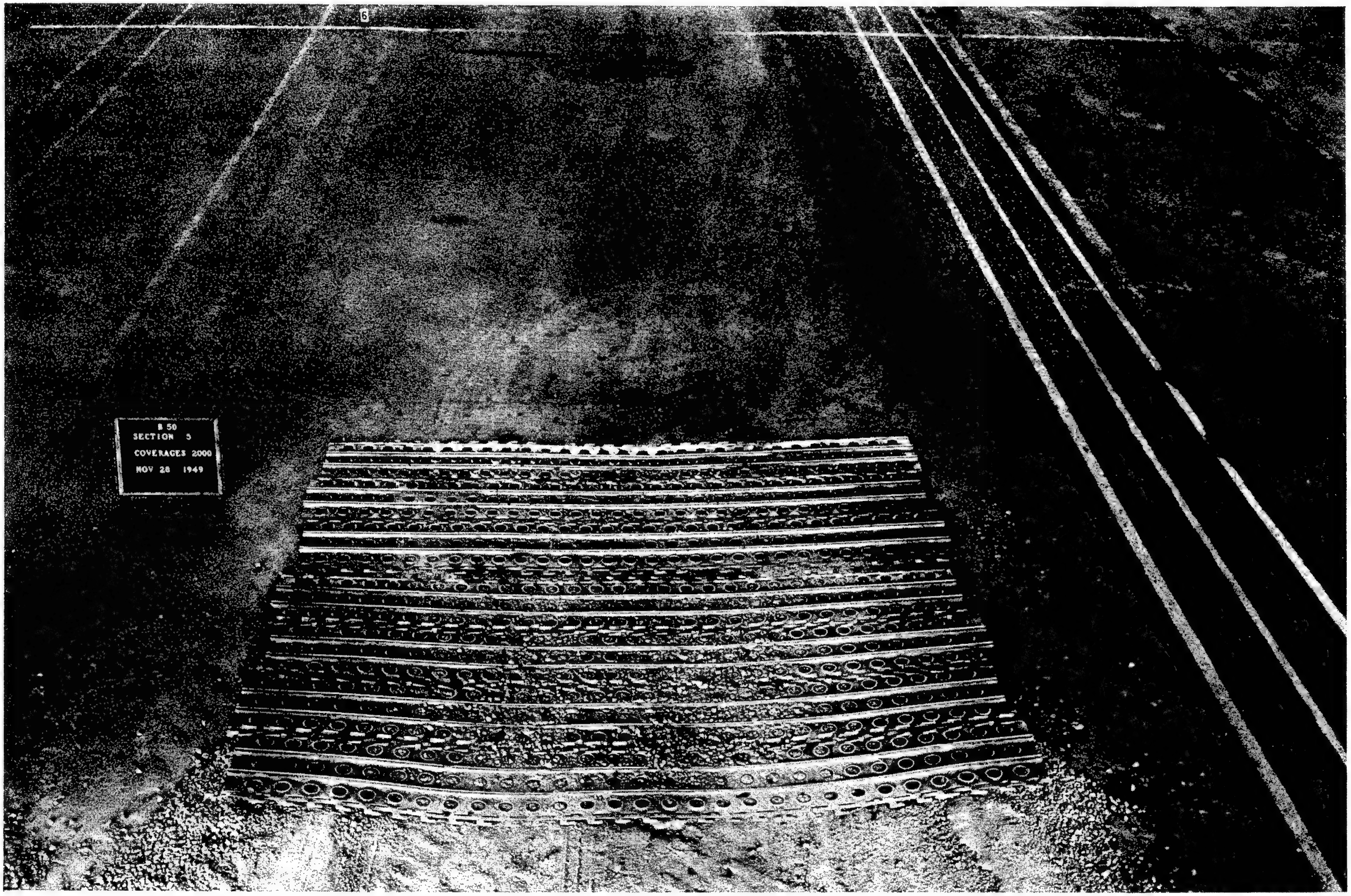
Photograph 16. Unit 4, 10-in. thickness. View showing condition of pavement after 42, 100, and 250 coverages with 100,000-lb load on B-50 assembly



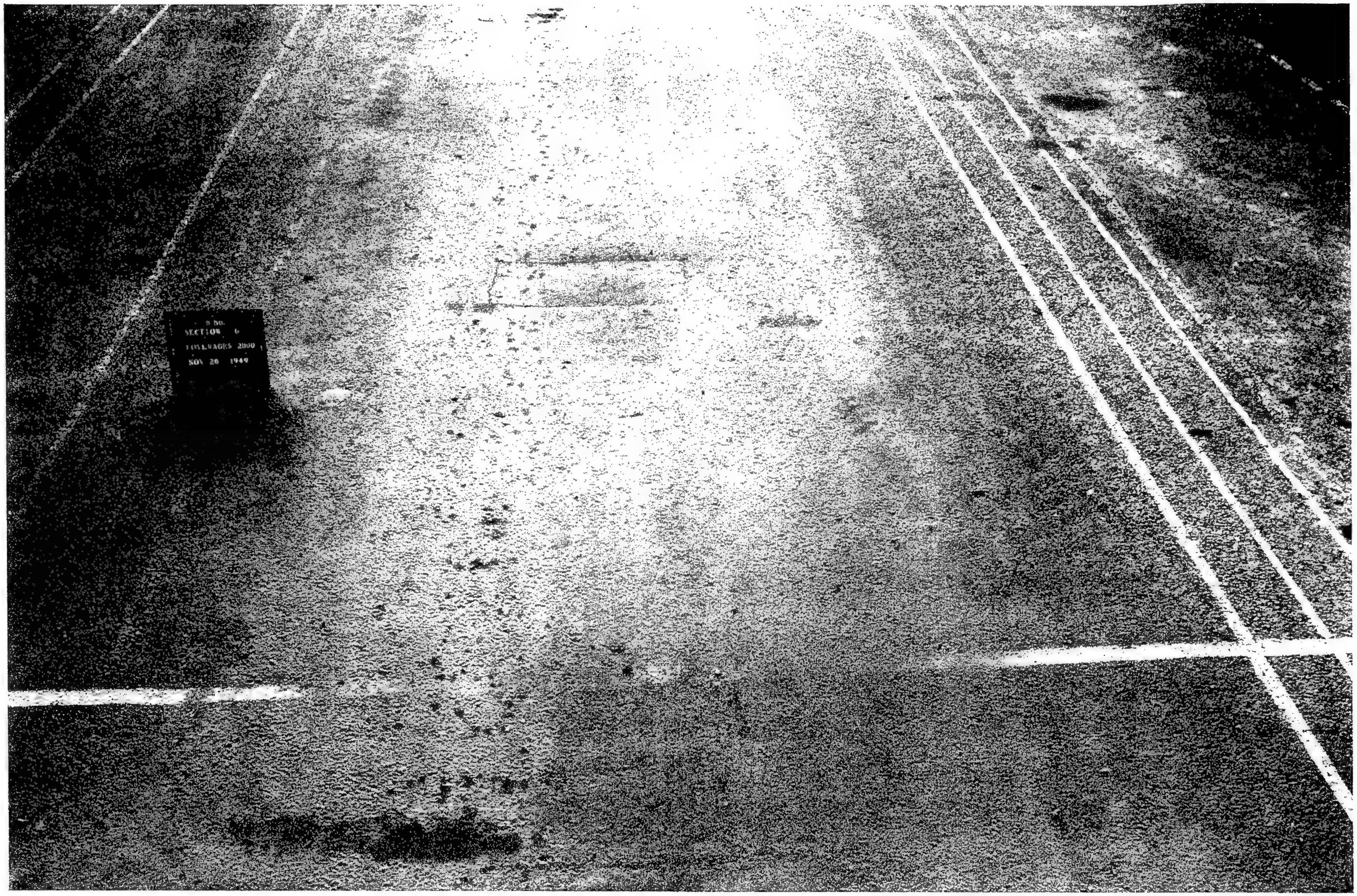
Photograph 17. Unit 4, 10-in. thickness. View showing condition of pavement after 328 coverages with 100,000-lb load on B-50 assembly



Photograph 18. Units 4 and 5, 10- and 15-in. thicknesses. View showing migration of cracks from 10- to 15-in. unit after 750 coverages with 100,000-lb load on B-50 assembly

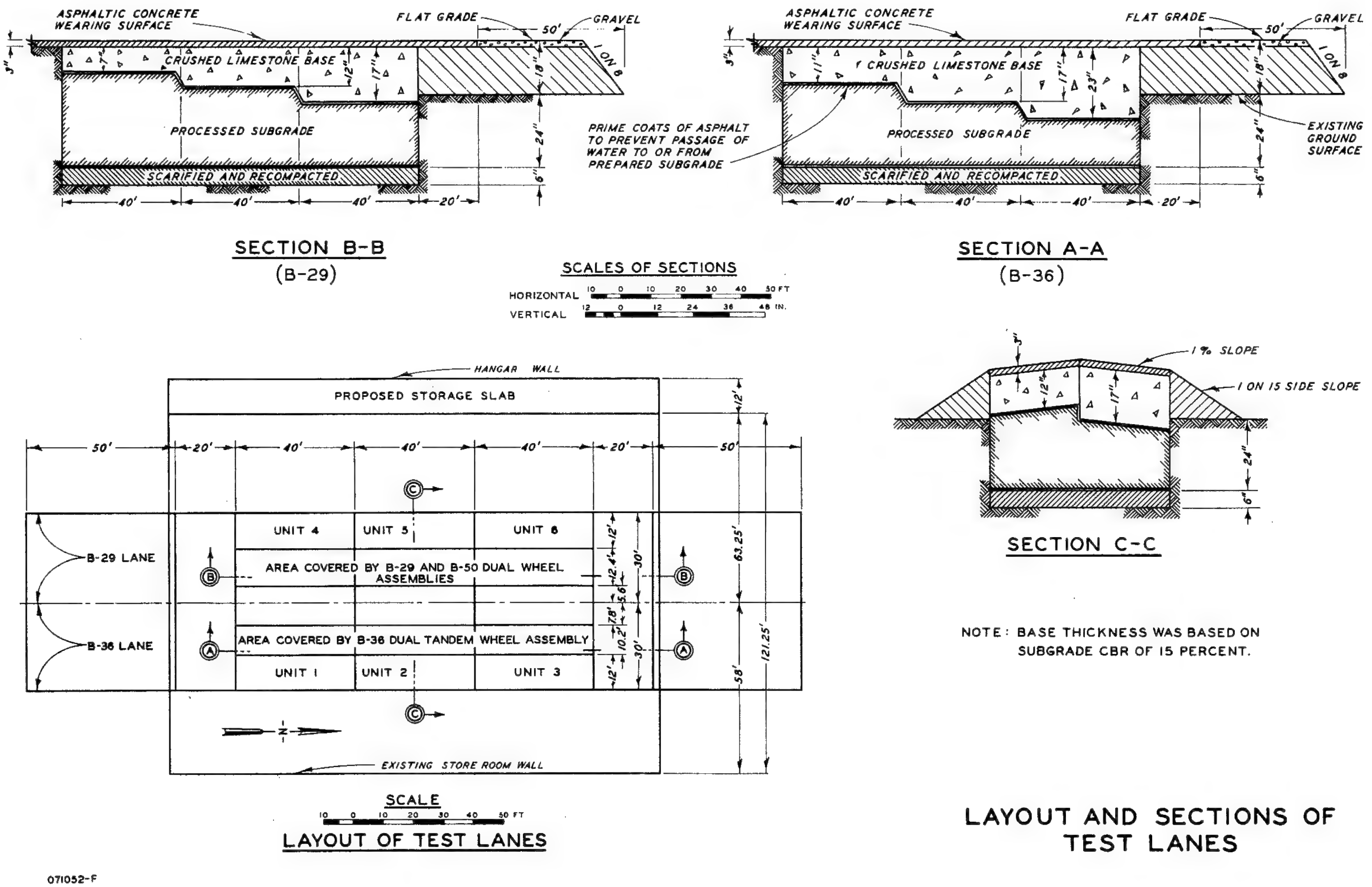


Photograph 19. Unit 5, 15-in. thickness. View showing condition of pavement after 2,000 coverages with 100,000-lb load on B-50 assembly

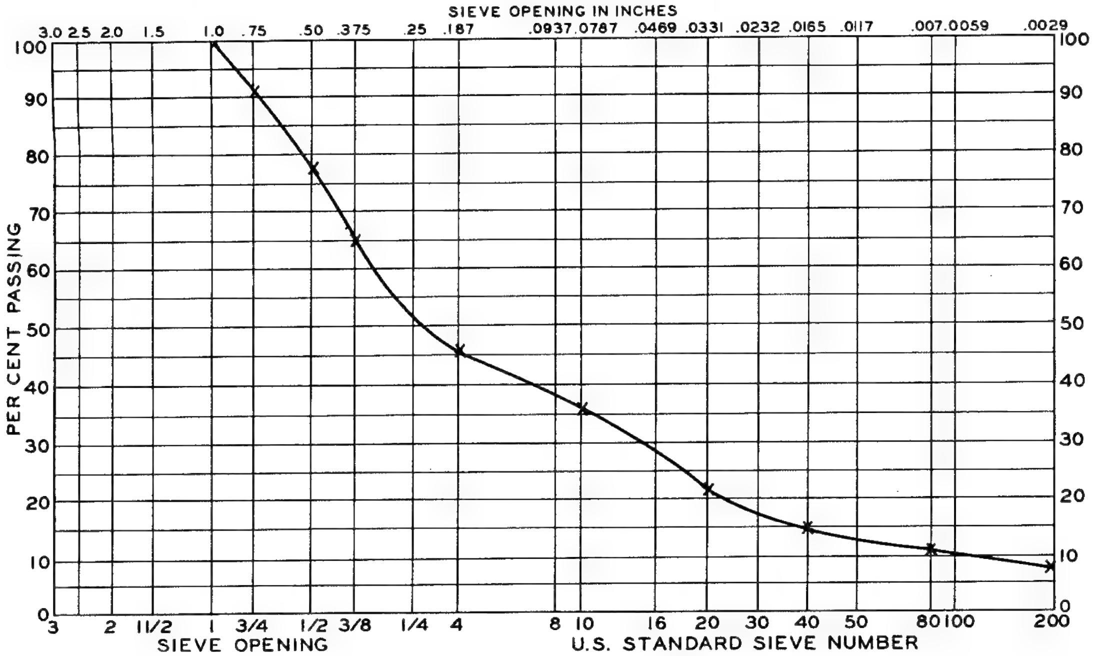


Photograph 20. Unit 6, 20-in. thickness. View showing condition of pavement after 2,000 coverages with 100,000-lb load on B-50 assembly

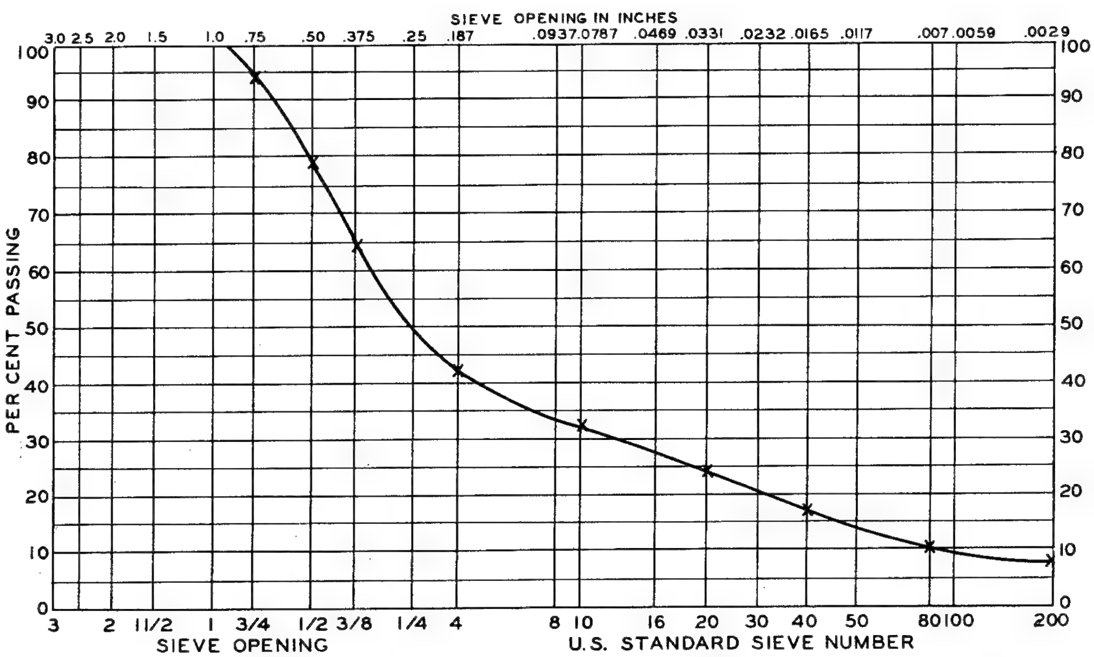
PLATES



LAYOUT AND SECTIONS OF TEST LANES



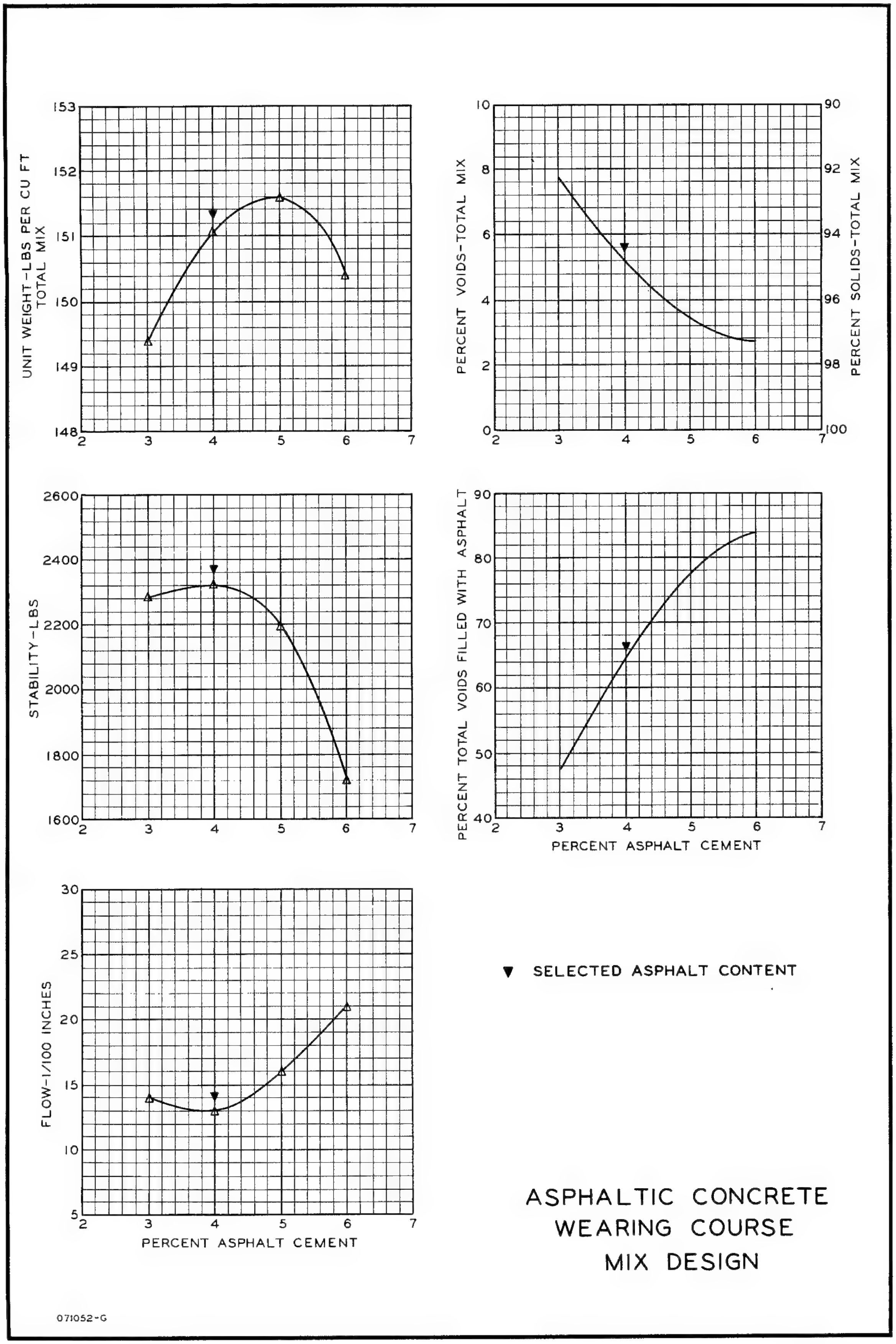
CRUSHED LIMESTONE BASE MATERIAL



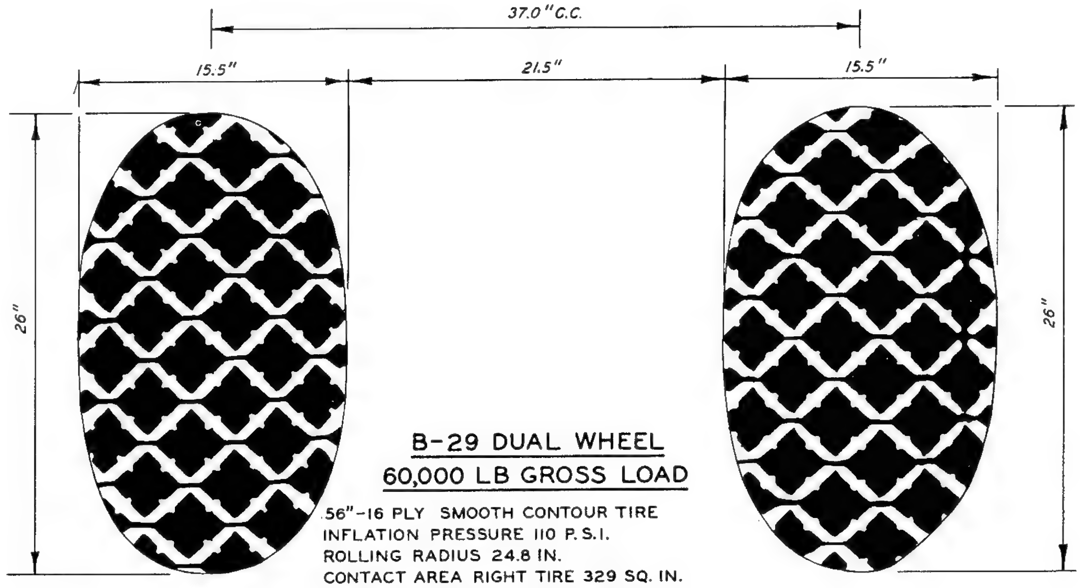
AGGREGATE FOR WEARING COURSE

TYPICAL MECHANICAL ANALYSIS
BASE AND WEARING COURSE

060452T

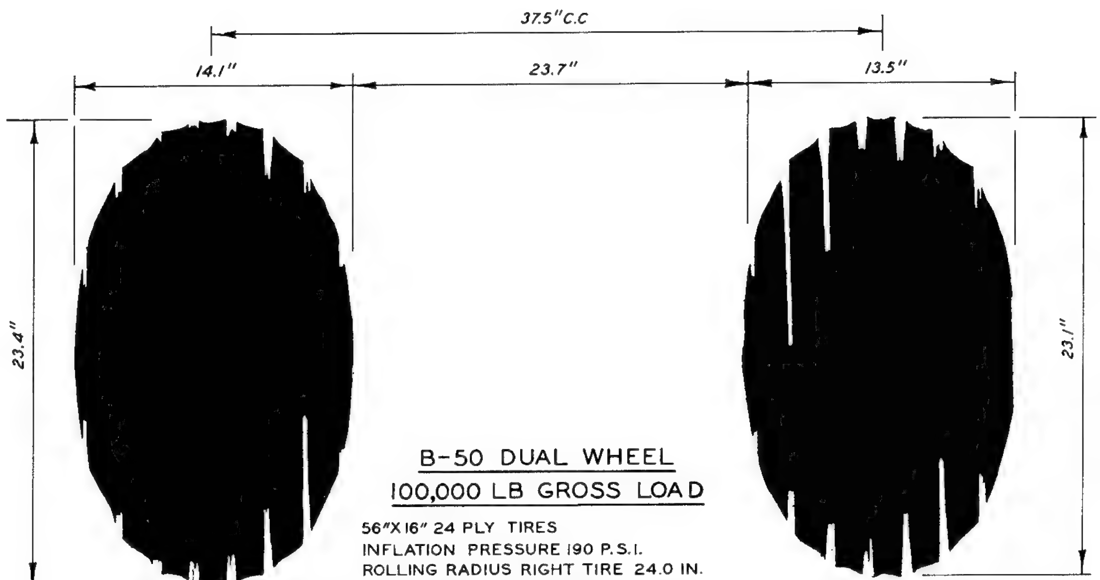


ASPHALTIC CONCRETE
WEARING COURSE
MIX DESIGN



B-29 DUAL WHEEL
60,000 LB GROSS LOAD

56"-16 PLY SMOOTH CONTOUR TIRE
INFLATION PRESSURE 110 P.S.I.
ROLLING RADIUS 24.8 IN.
CONTACT AREA RIGHT TIRE 329 SQ. IN.
CONTACT AREA LEFT TIRE 328 SQ. IN.
AVERAGE CONTACT PRESSURE 91.3 P.S.I.



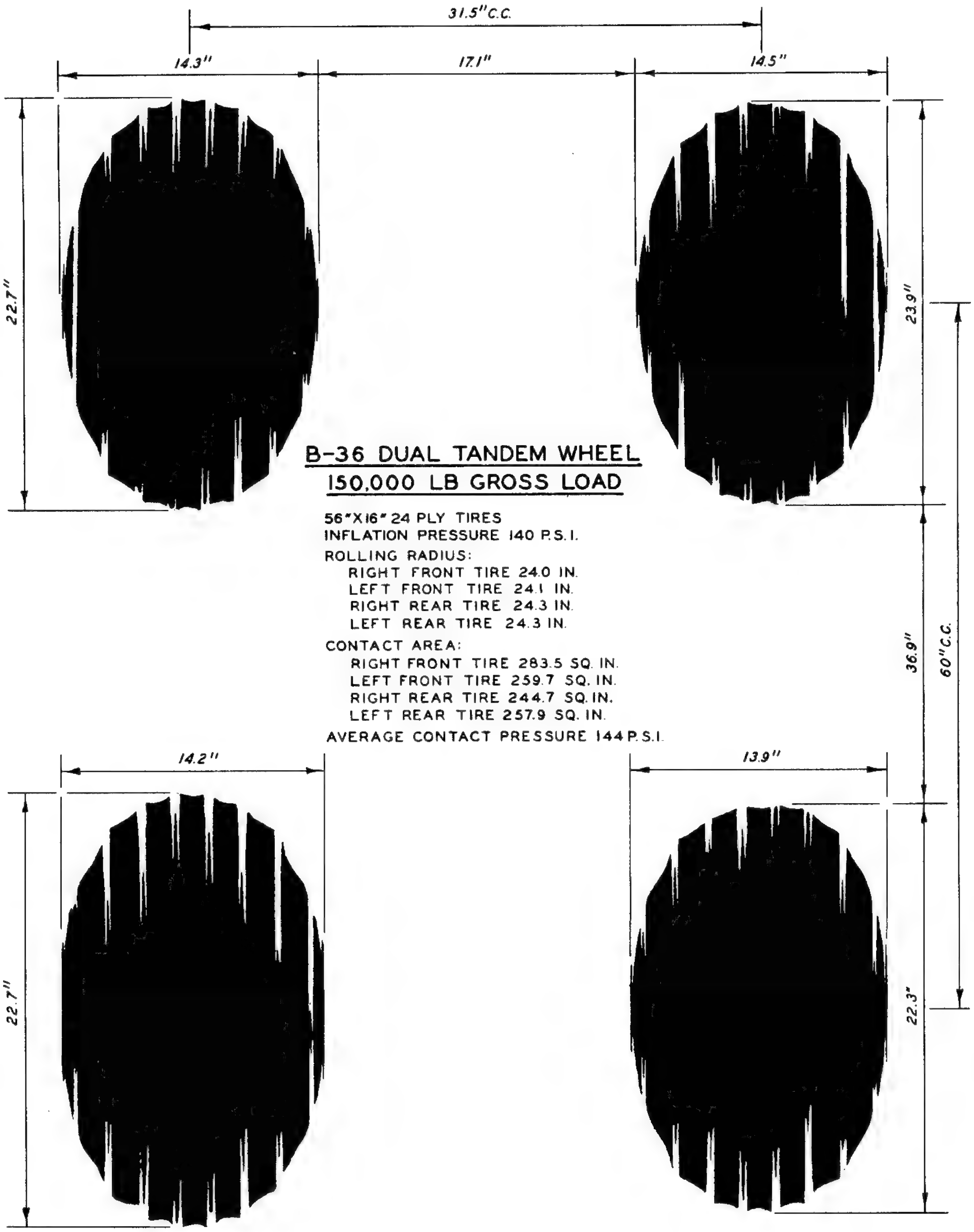
B-50 DUAL WHEEL
100,000 LB GROSS LOAD

56"X16" 24 PLY TIRES
INFLATION PRESSURE 190 P.S.I.
ROLLING RADIUS RIGHT TIRE 24.0 IN.
ROLLING RADIUS LEFT TIRE 24.1 IN.
CONTACT AREA RIGHT TIRE 252.9 SQ.IN.
CONTACT AREA LEFT TIRE 262.8 SQ.IN.
AVERAGE CONTACT PRESSURE 194 P.S.I.

B-29 AND B-50 TIRE PRINTS

071052-H

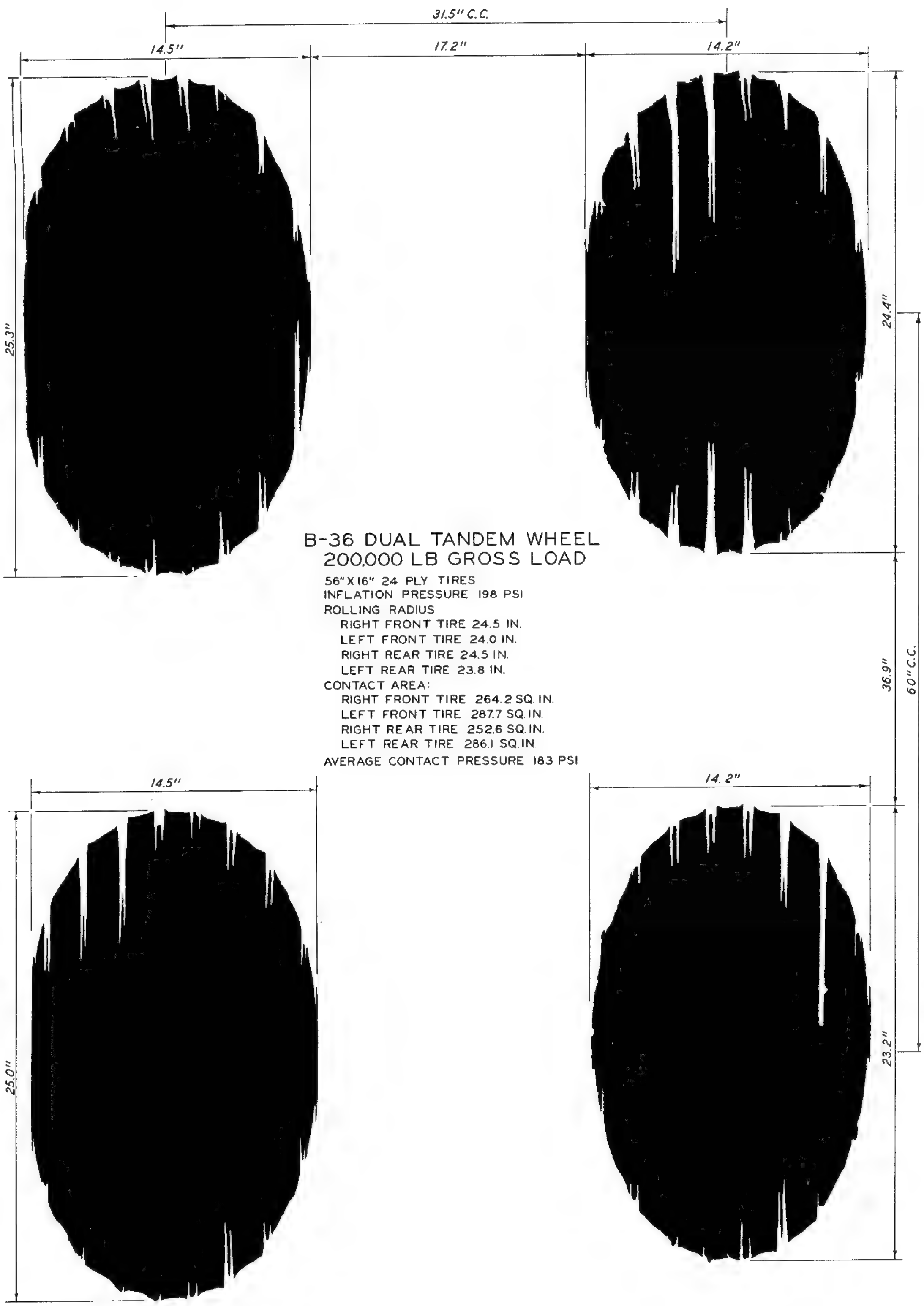
PLATE 4



B-36 TIRE PRINTS

150,000-LB LOAD

071052-J

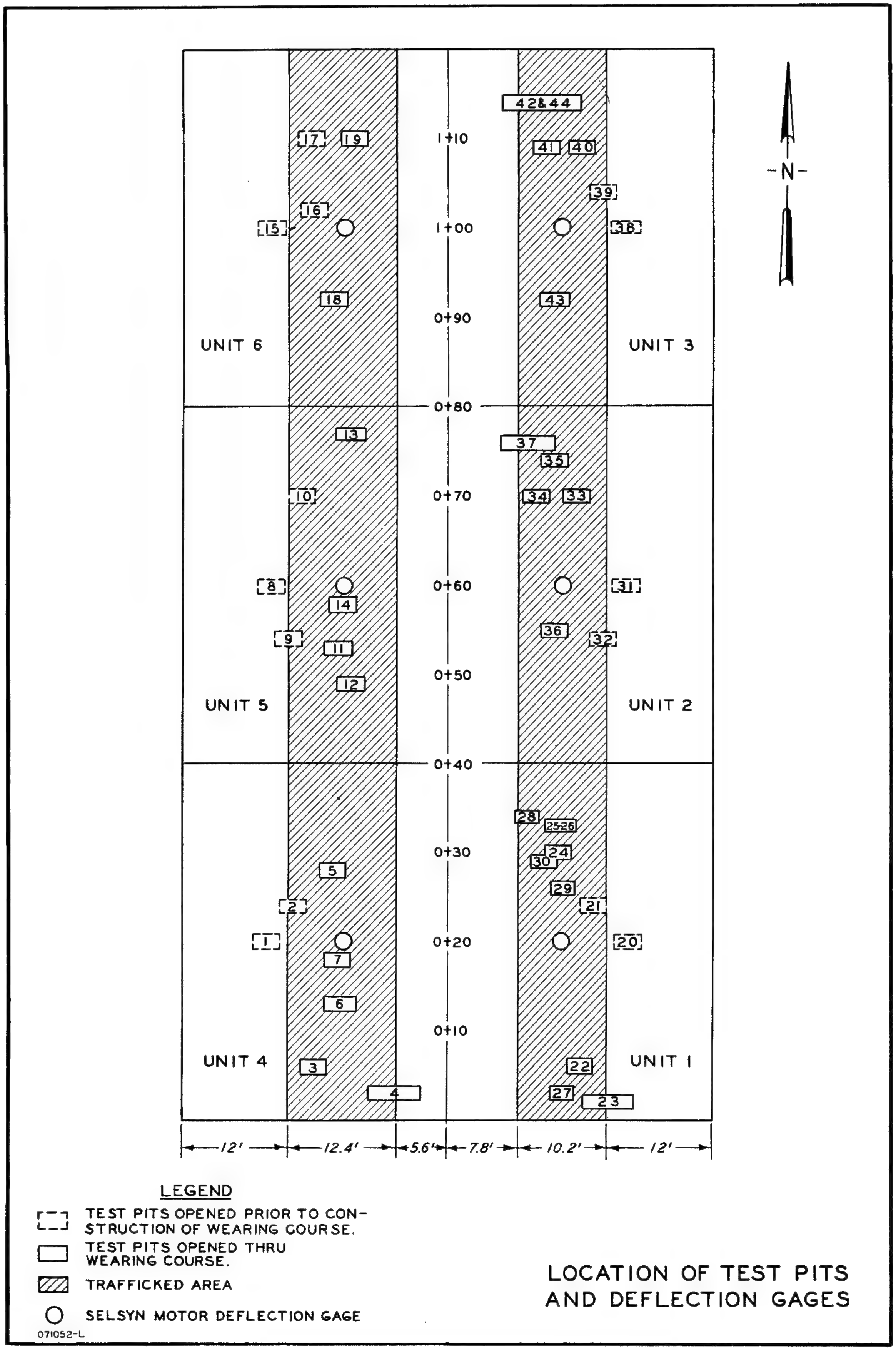


B-36 TIRE PRINTS

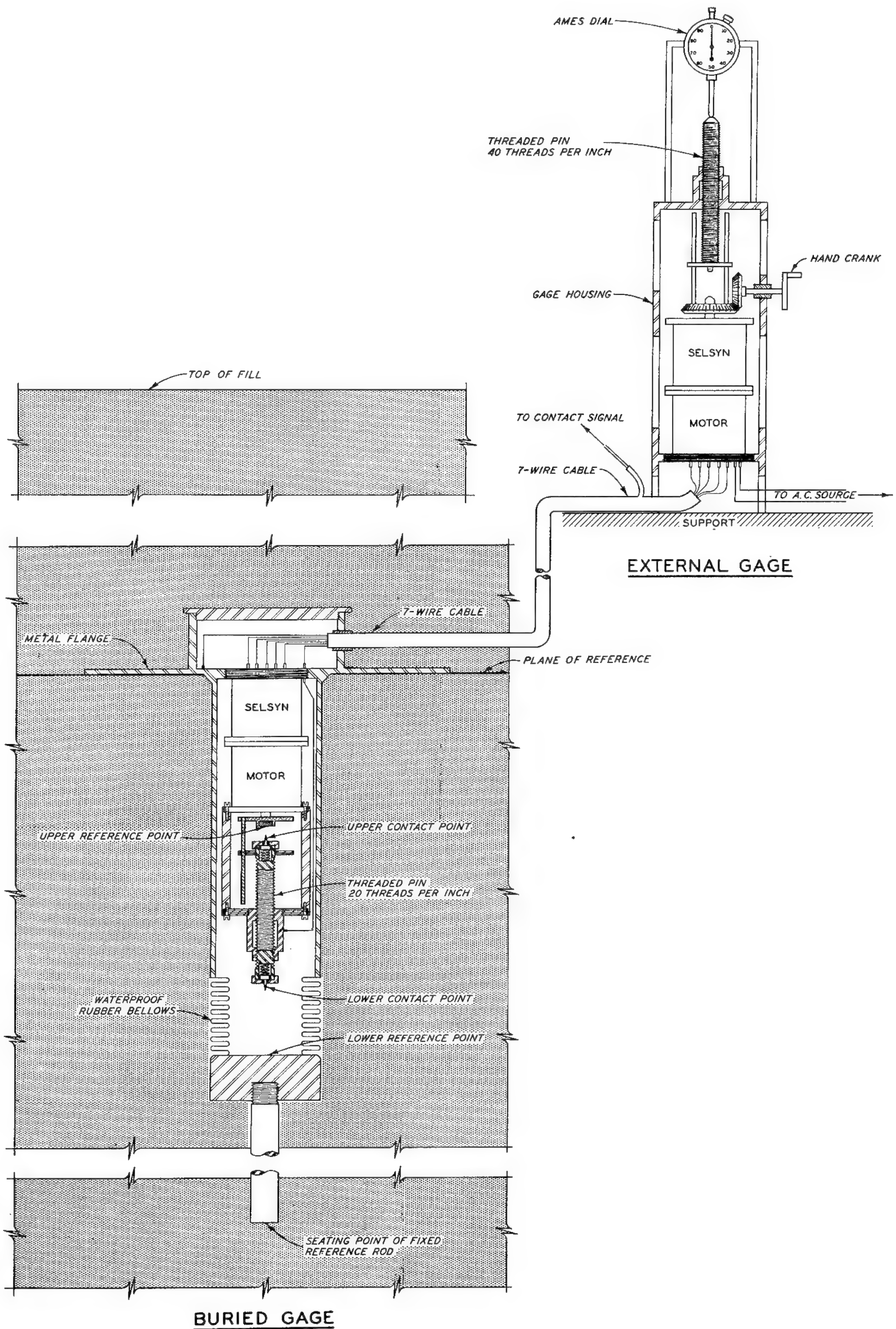
200,000-LB LOAD

071052-K

PLATE 6



LOCATION OF TEST PITS
AND DEFLECTION GAGES

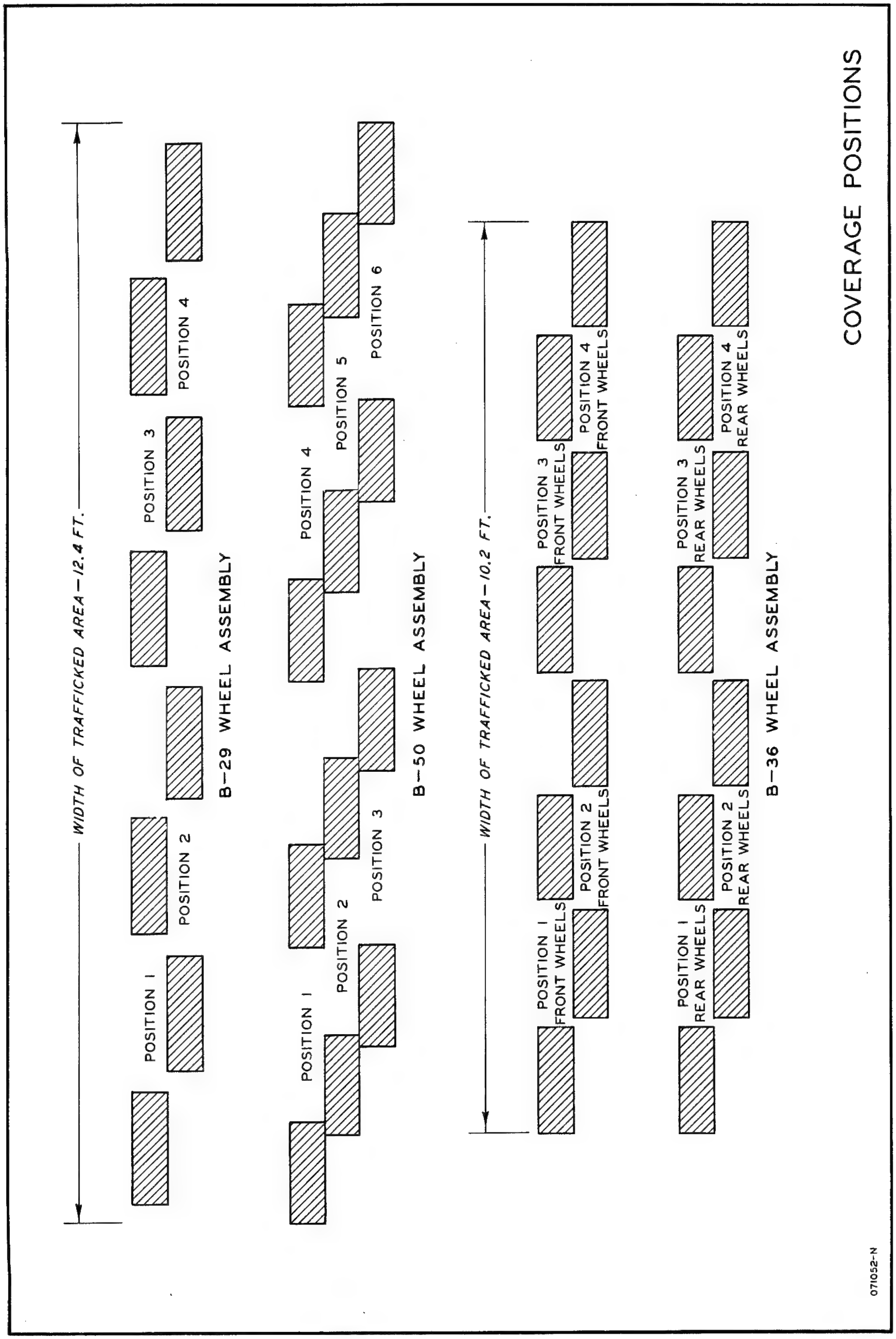


SCHEMATIC DRAWING

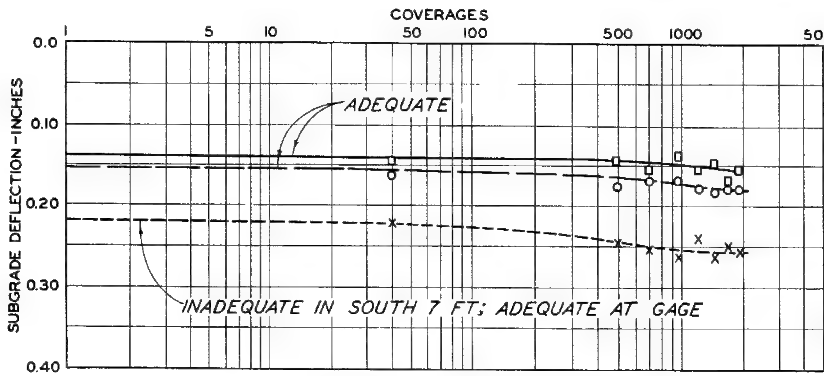
EXTERNAL AND BURIED
SELSYN DEFLECTION GAGES

071052-M

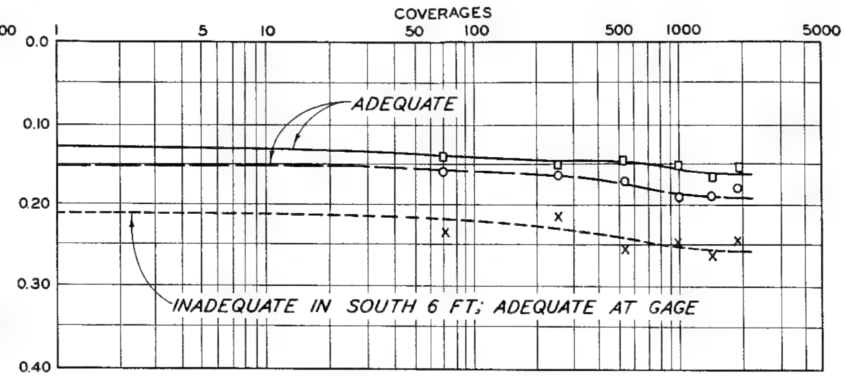
PLATE 8



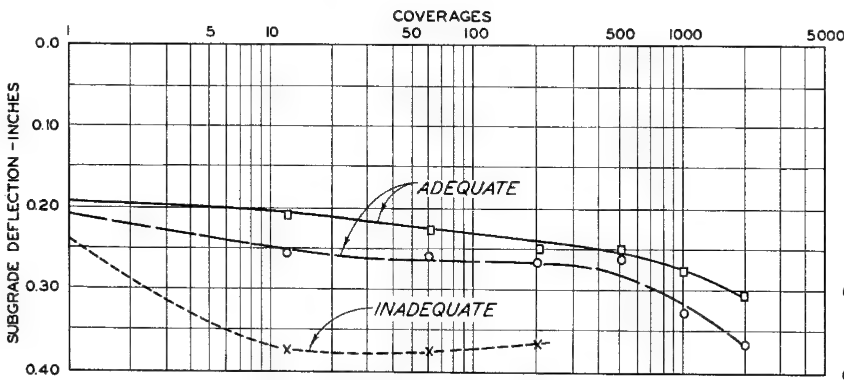
COVERAGE POSITIONS



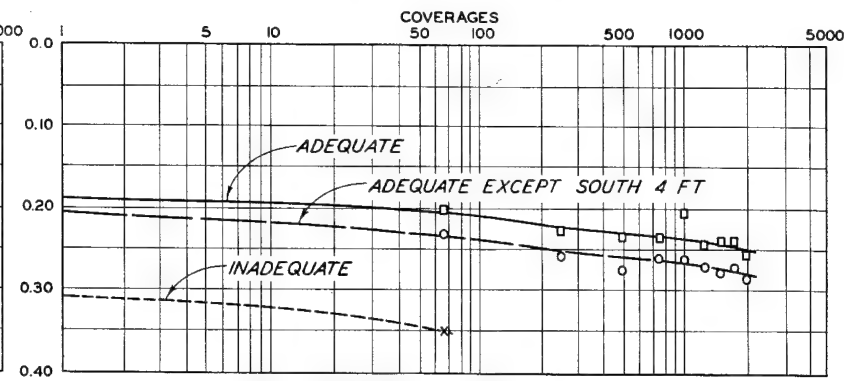
B-36 150,000-LB ASSEMBLY LOAD
UNITS 1, 2, AND 3



B-29 70,000-LB ASSEMBLY LOAD
UNITS 4, 5, AND 6



B-36 200,000-LB ASSEMBLY LOAD
UNITS 1, 2, AND 3



B-50 100,000-LB ASSEMBLY LOAD
UNITS 4, 5, AND 6

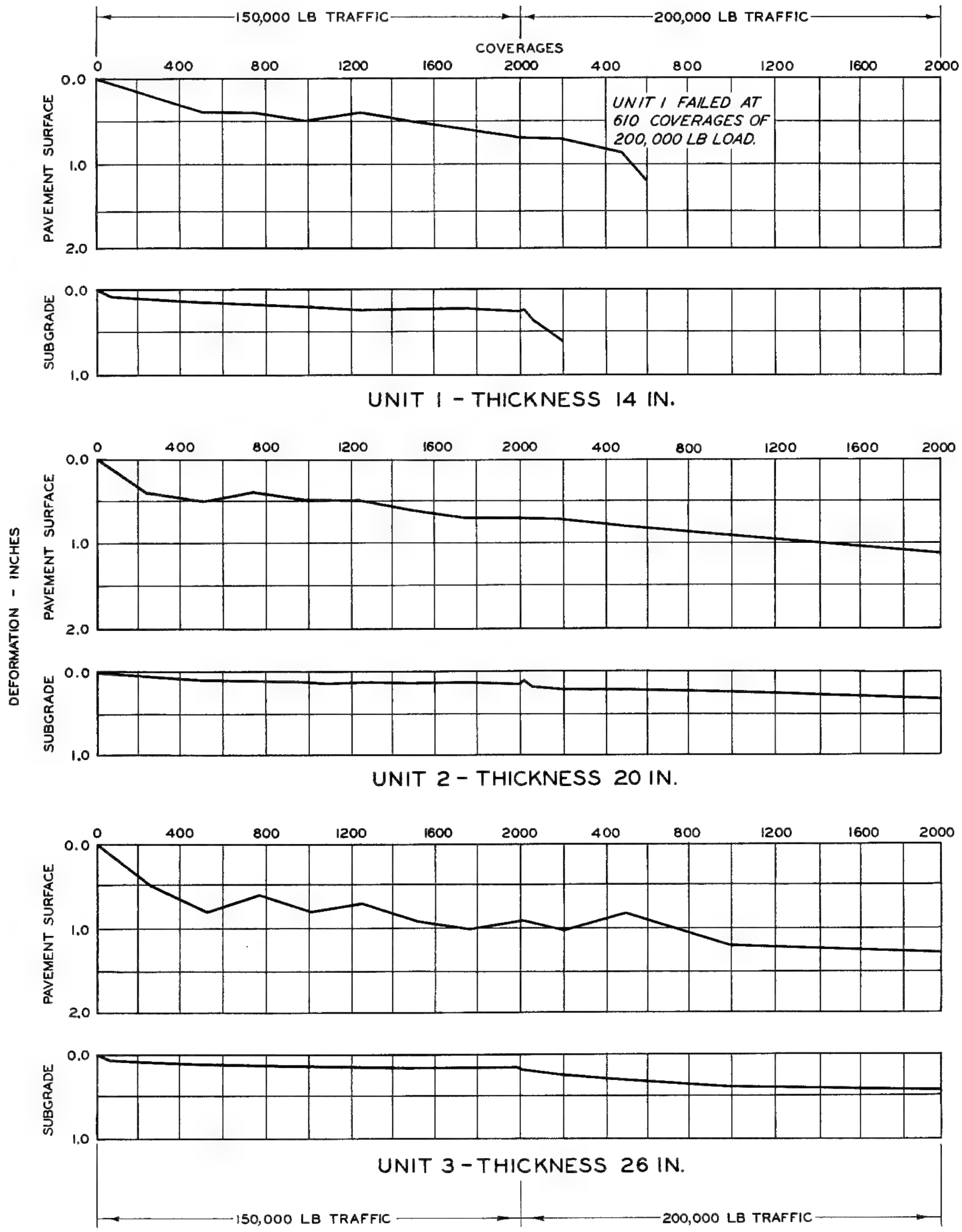
NOTES: THICKNESSES (TOTAL OF PAVEMENT AND BASE) FOR THE SIX UNITS ARE AS FOLLOWS:

X-------	UNIT 1 - 14 IN.	UNIT 4 - 10 IN.
O— — —	UNIT 2 - 20 IN.	UNIT 5 - 15 IN.
□———	UNIT 3 - 26 IN.	UNIT 6 - 20 IN.

DEFLECTION WAS MEASURED AT ONLY ONE POINT IN EACH UNIT.

SUBGRADE DEFLECTION VS COVERAGE

060452U



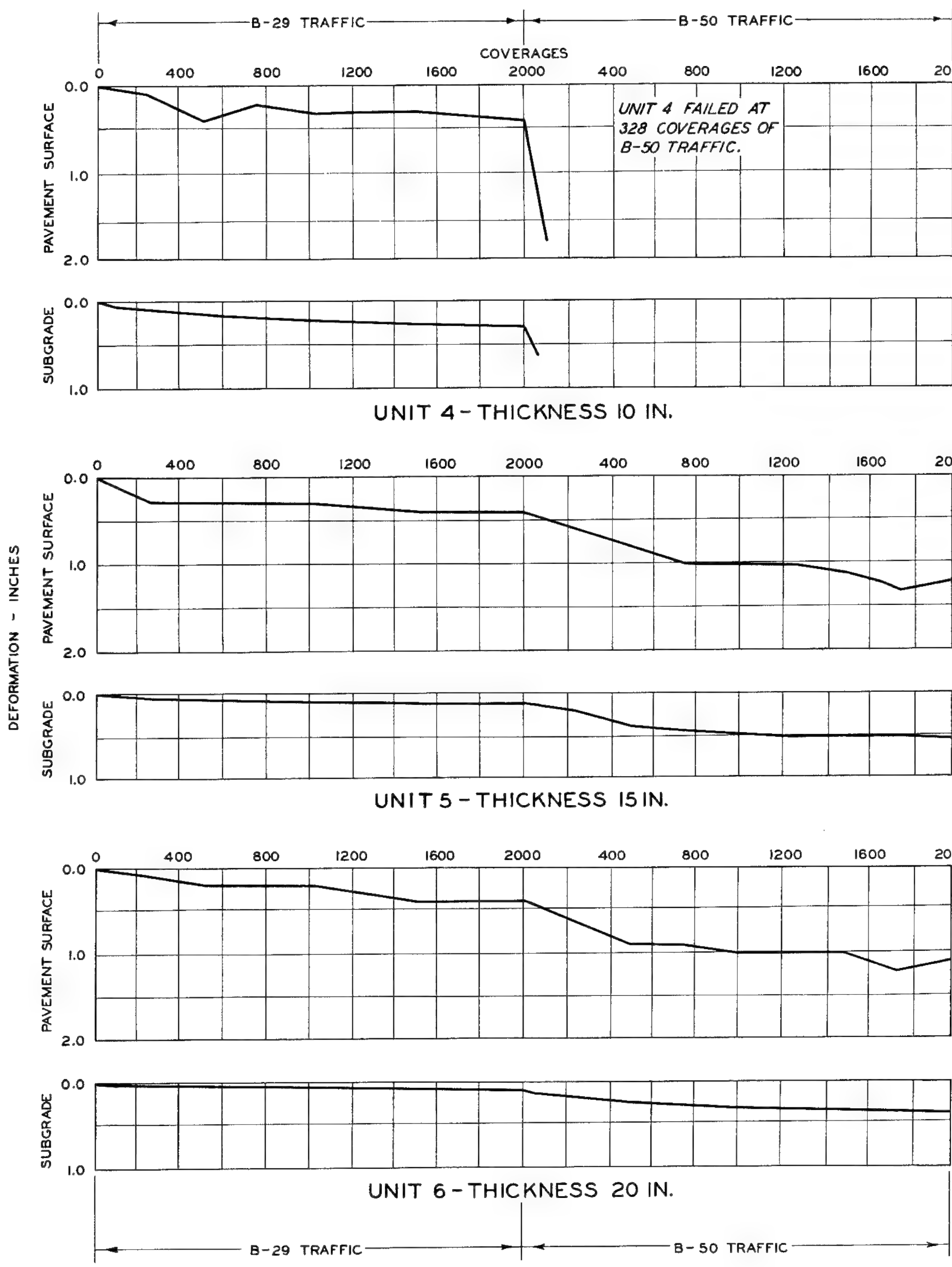
NOTE: IN UNITS 1, 2 AND 3, GAGES WERE LOCATED 13 FT RIGHT OF ℄ AND AT STATIONS 0+20, 0+60 AND 1+00, RESPECTIVELY.

THICKNESS REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

DEFORMATION AT GAGE POINTS VS COVERAGES

B-36

071052-P



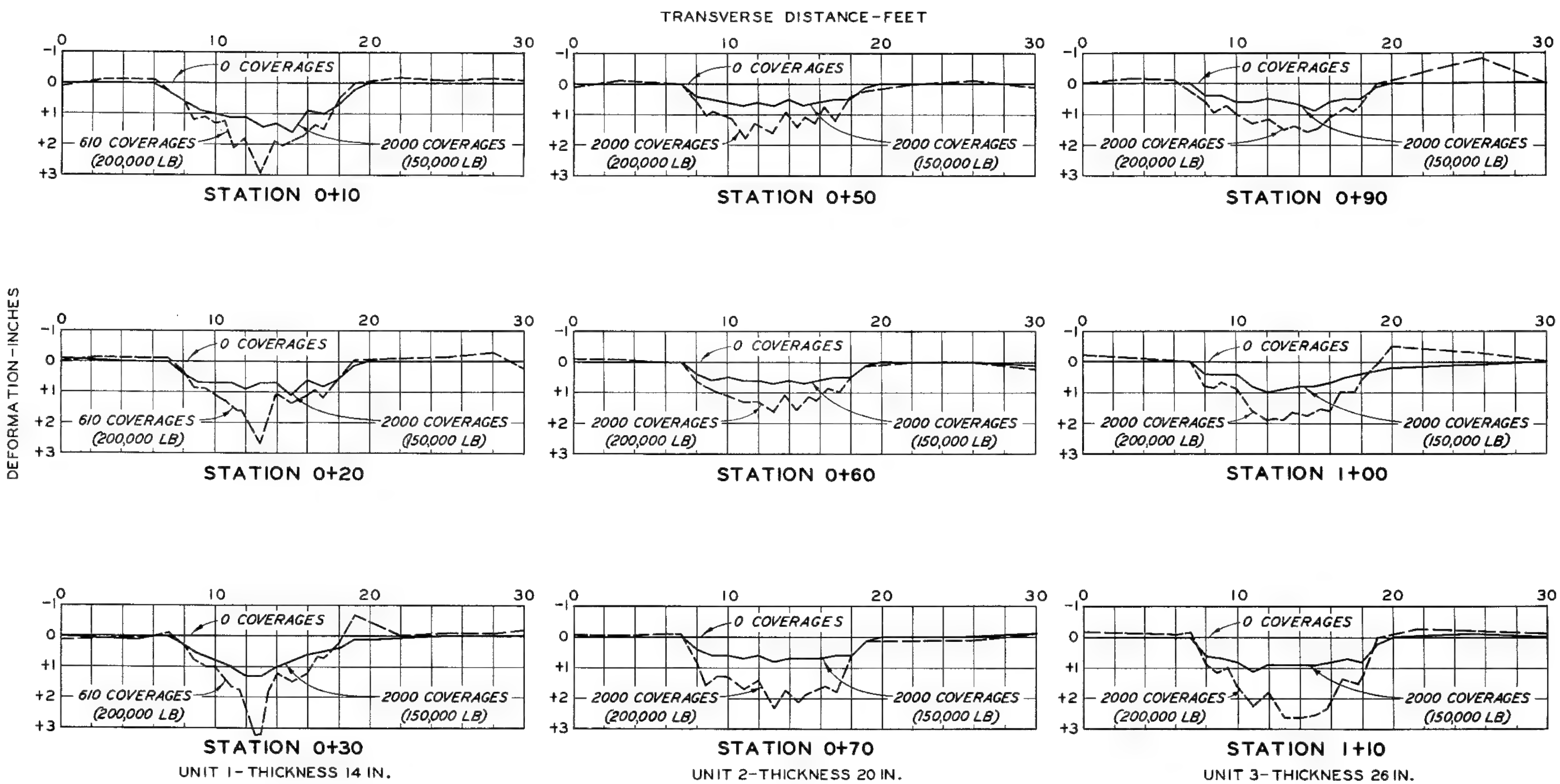
NOTE: IN UNITS 4, 5 AND 6, GAGES WERE LOCATED 12 FT LEFT OF ℄ AND AT STATIONS 0+20, 0+60 AND 1+00, RESPECTIVELY.

THICKNESS REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

DEFORMATION AT GAGE POINTS VS COVERAGES

B-29 AND B-50

071052-Q

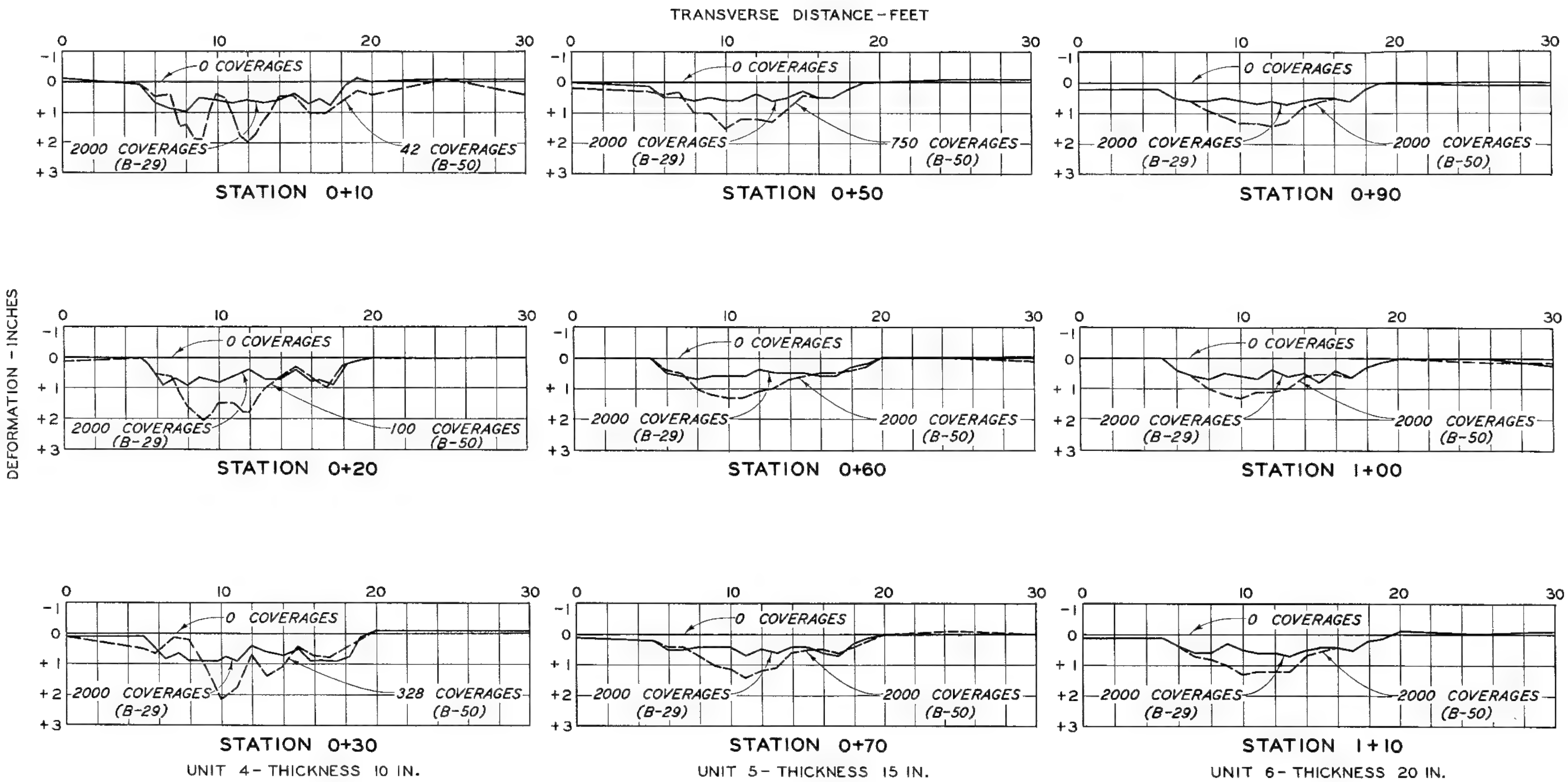


NOTE: THICKNESS REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

PAVEMENT DEFORMATION

B-36 ASSEMBLY

071052-R

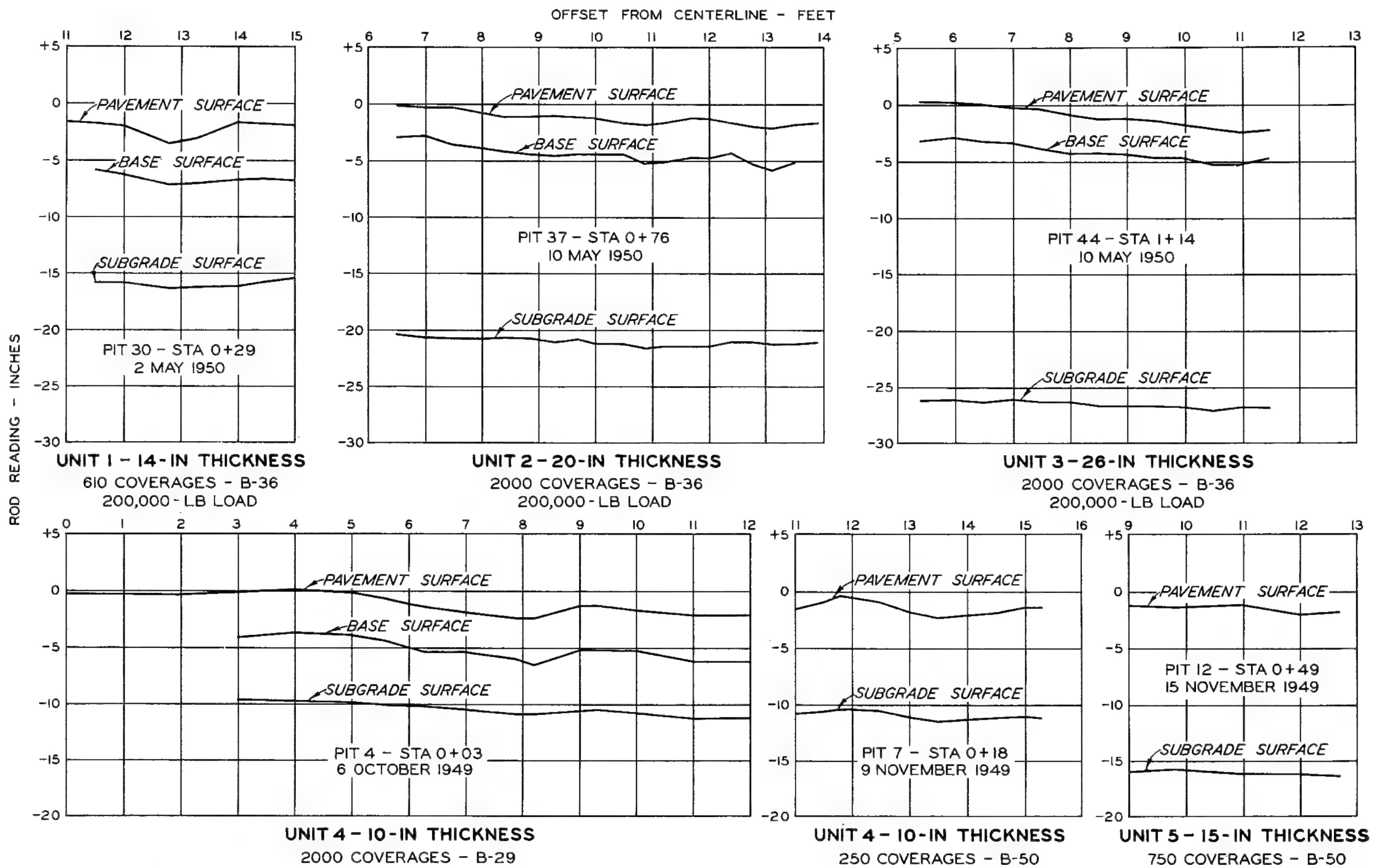


NOTE: THICKNESS REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

PAVEMENT DEFORMATION

B-29 AND B-50 ASSEMBLIES

071052-S



NOTE: THICKNESS REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE

PROFILES OF CBR PITS

071052-T

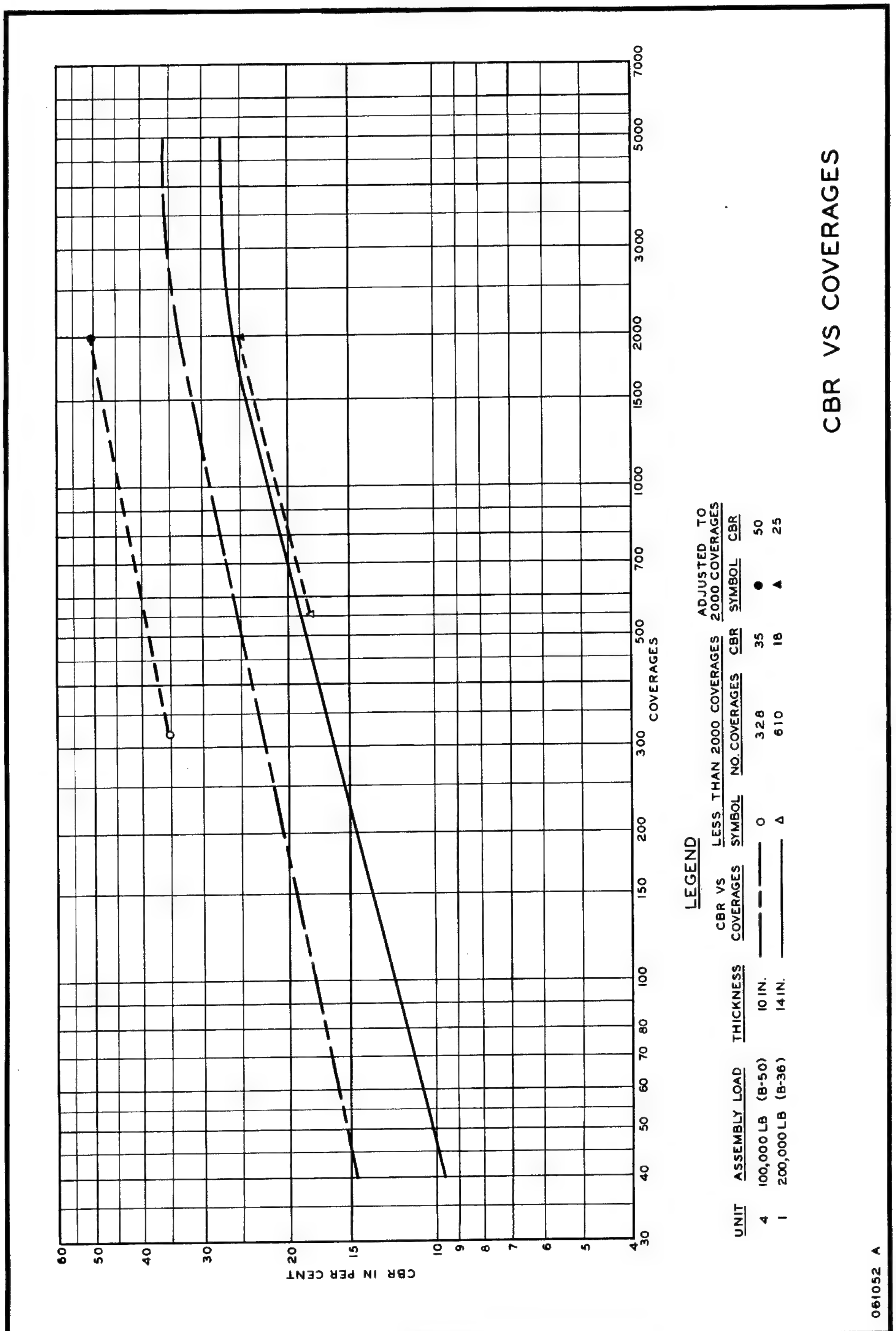
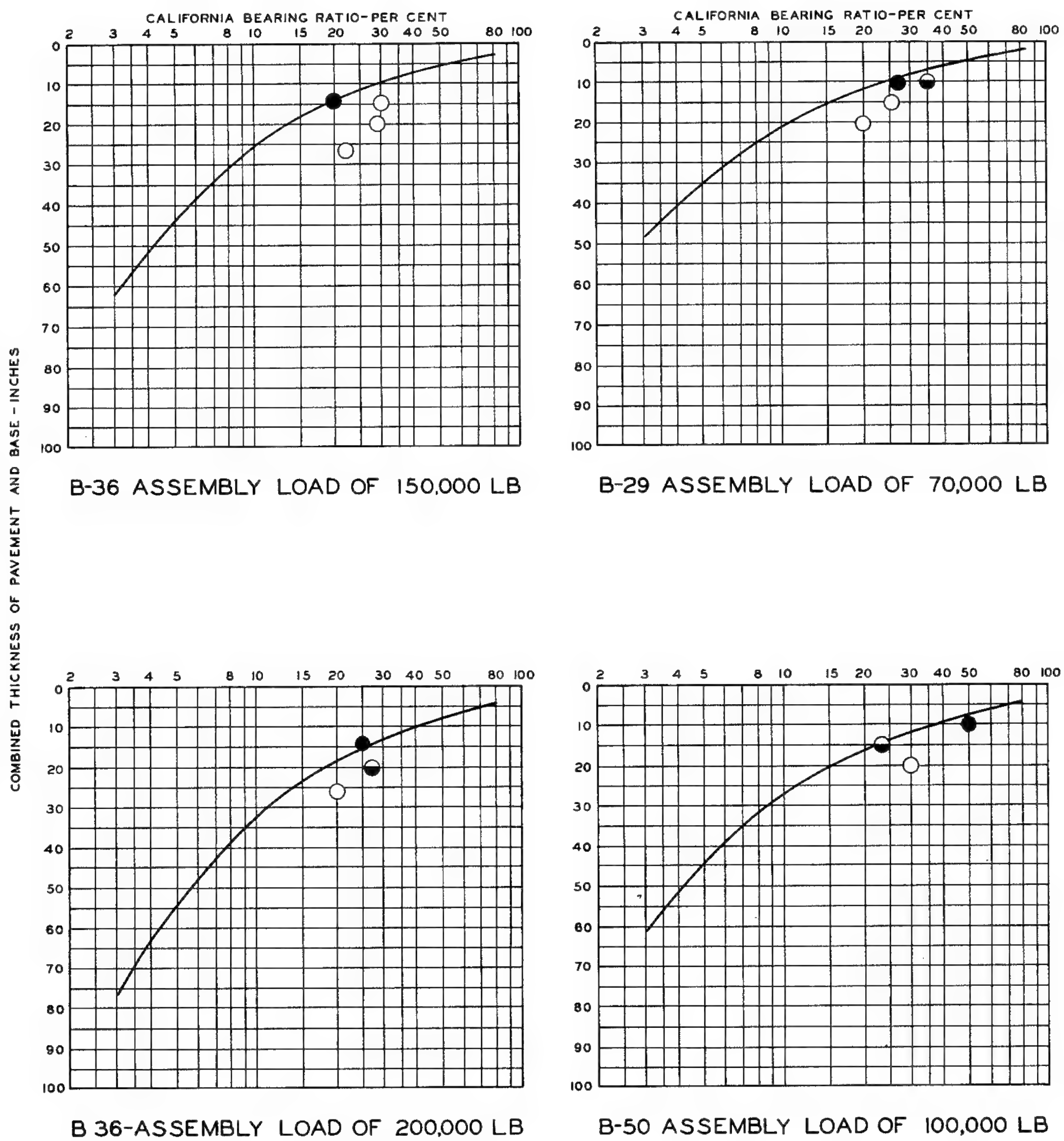

CBR VS COVERAGES
CBR IN PER CENT
60 50 40 30 20 15 10 9 8 7 6 5 4
COVERAGES
30 40 50 60 70 80 100 150 200 300 500 700 1000 1500 2000 3000 5000 7000
LEGEND
UNIT ASSEMBLY LOAD THICKNESS CBR VS COVERAGES
LESS THAN 2000 COVERAGES: SYMBOL NO. COVERAGES CBR
ADJUSTED TO 2000 COVERAGES: SYMBOL CBR
4 100,000 LB (B-50) 10 IN. o 328 35 ● 50
1 200,000 LB (B-36) 14 IN. Δ 610 18 ▲ 25
061052 A

PLATE 16

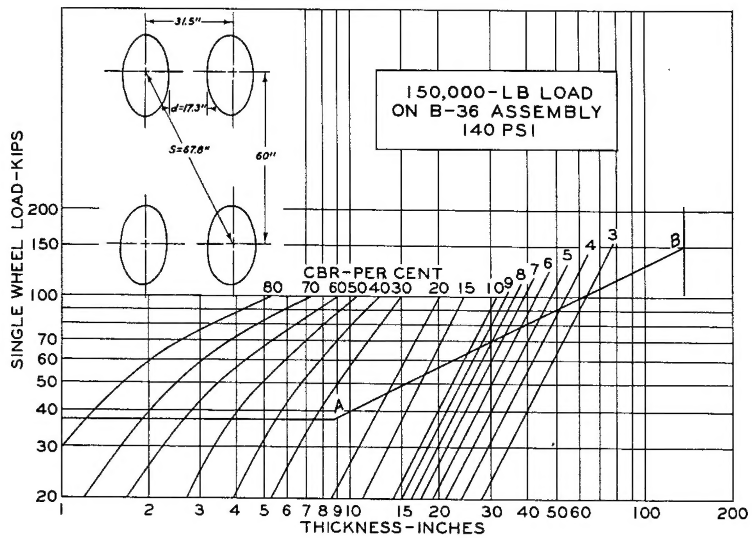


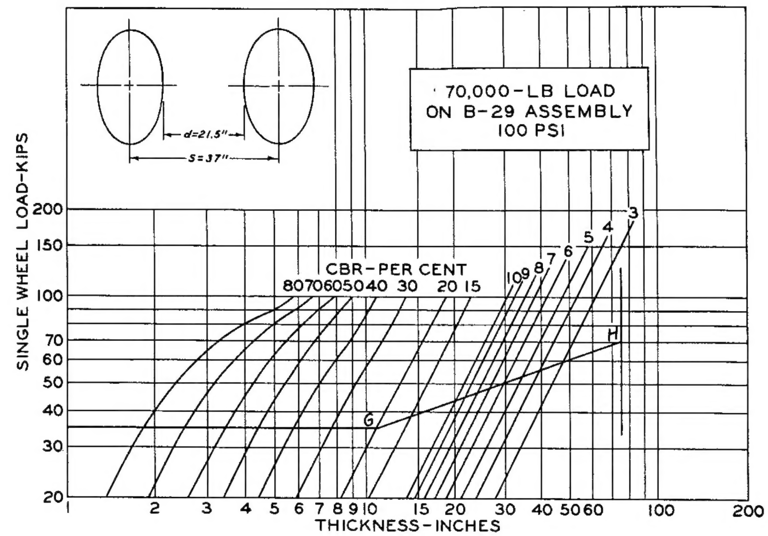
LEGEND

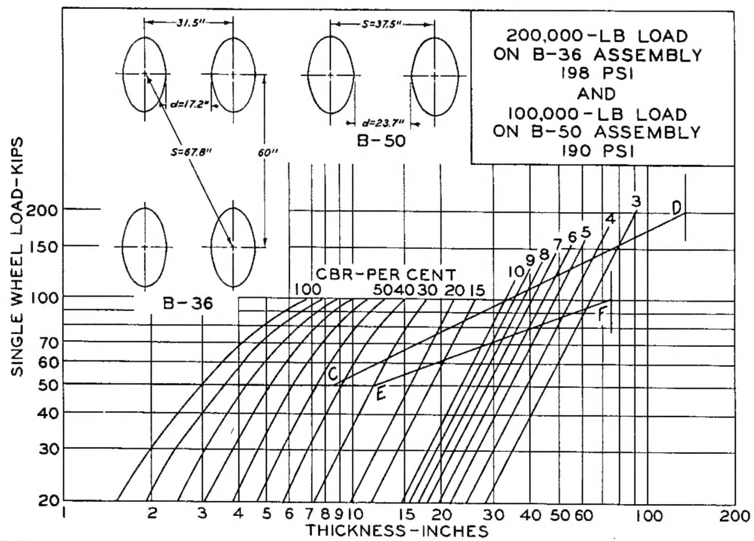
- ● INADEQUATE
- ◒ BORDERLINE
- ○ ADEQUATE
- — CURVE OBTAINED BY THEORETICAL RESOLUTION OF SINGLE WHEEL CURVES.

DESIGN THICKNESSES BASED ON VISUAL OBSERVATIONS

R102251 I

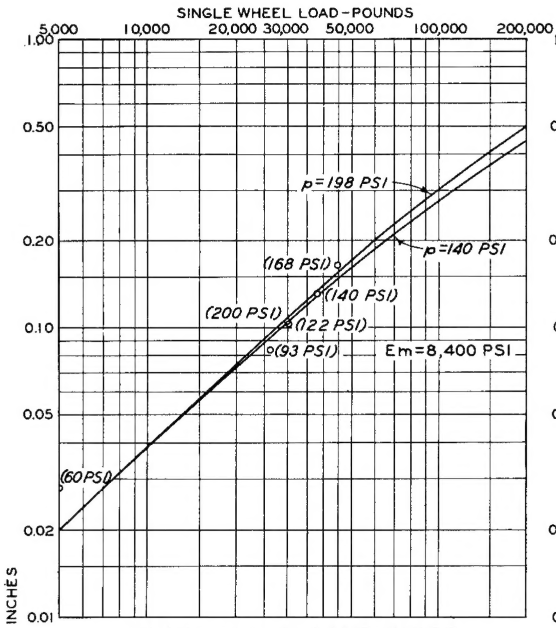




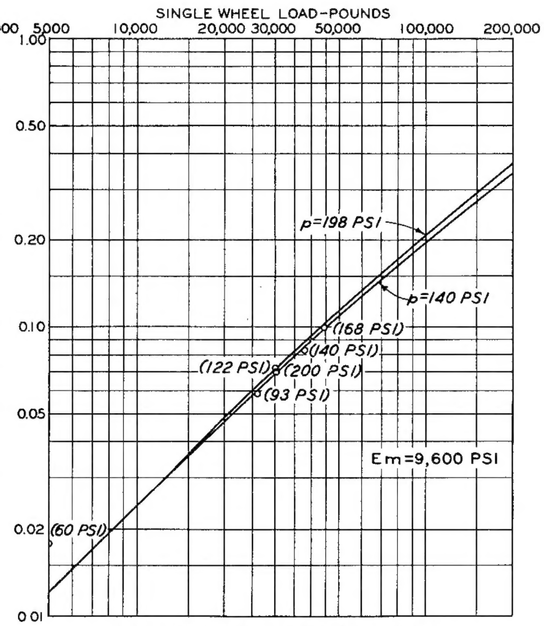


071052-U

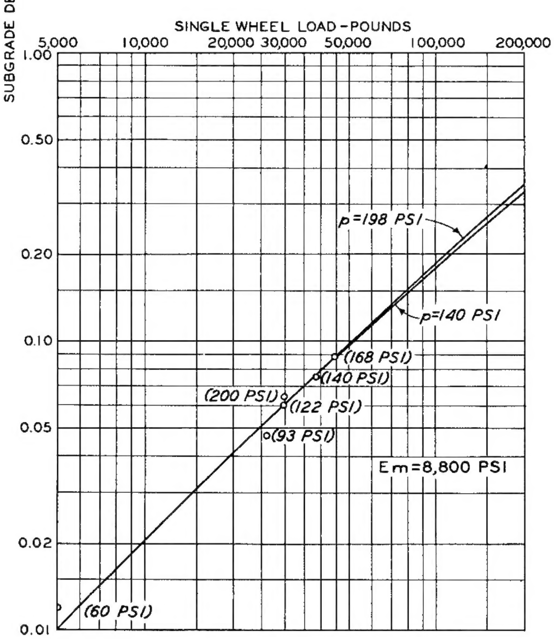
DEVELOPMENT OF MULTIPLE WHEEL DESIGN CURVES



UNIT 1-14-IN. THICKNESS



UNIT 2-20-IN THICKNESS



UNIT 3-26-IN. THICKNESS

NOTES

POINTS ARE ACTUAL TEST DATA. FIGURES IN PARENTHESES ARE TIRE INFLATION PRESSURE OF TEST LOADS.

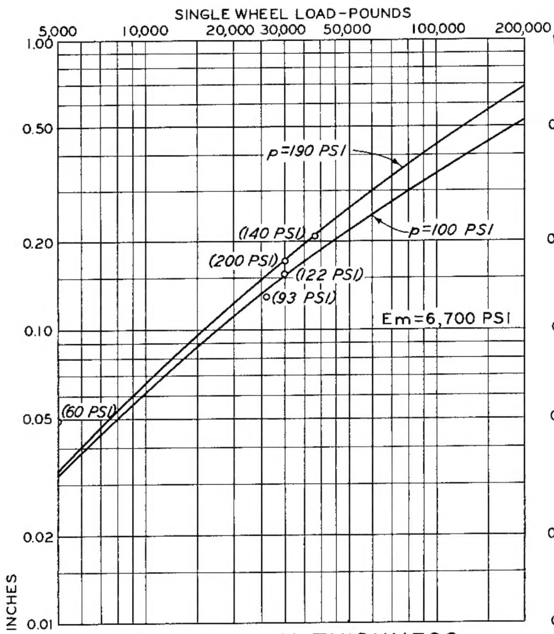
CURVES ARE COMPUTED FROM THE FORMULA $\omega = \frac{3P}{2\pi E_m \sqrt{Z^2+r^2}}$ USING VALUE OF MODULUS OF ELASTICITY (Em) INDICATED.

THICKNESS (Z) REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

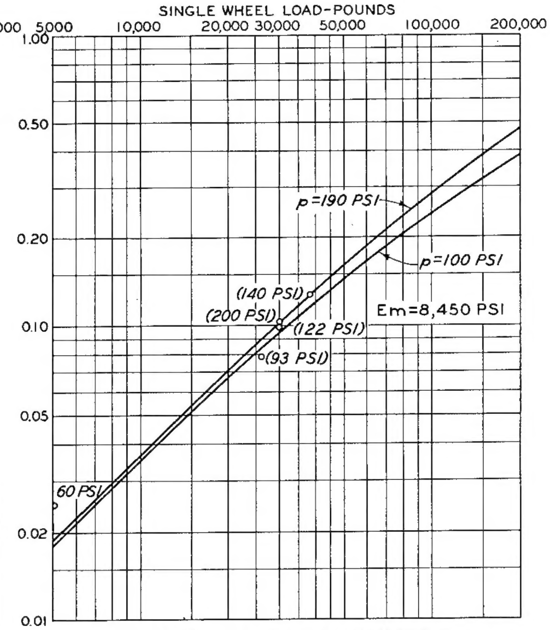
SUBGRADE DEFLECTION VS SINGLE WHEEL LOAD

UNITS 1, 2, AND 3 — B-36 LANE

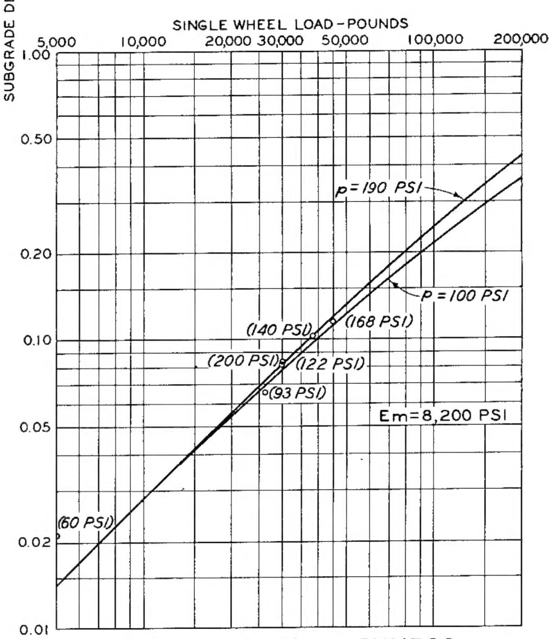
071052-V



UNIT 4-10-IN. THICKNESS



UNIT 5- 15-IN THICKNESS



UNIT 6-20-IN. THICKNESS

NOTES

POINTS ARE ACTUAL TEST DATA. FIGURES IN PARENTHESES ARE TIRE INFLATION PRESSURE OF TEST LOADS.

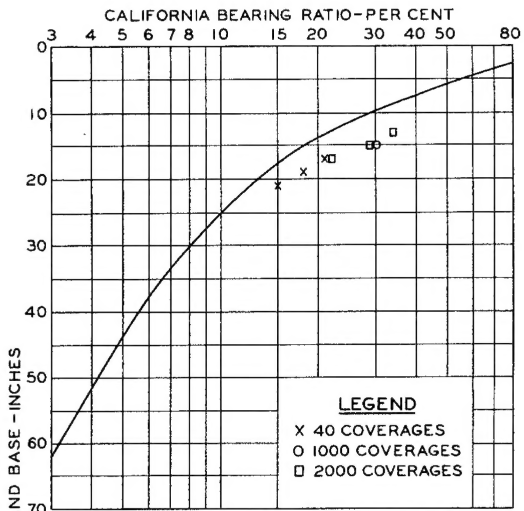
CURVES ARE COMPUTED FROM THE FORMULA $\omega = \frac{3P}{2\pi E_m \sqrt{Z^2+r^2}}$ USING VALUE OF MODULUS OF ELASTICITY (Em) INDICATED.

THICKNESS (Z) REFERS TO COMBINED THICKNESS OF PAVEMENT AND BASE.

SUBGRADE DEFLECTION VS SINGLE WHEEL LOAD

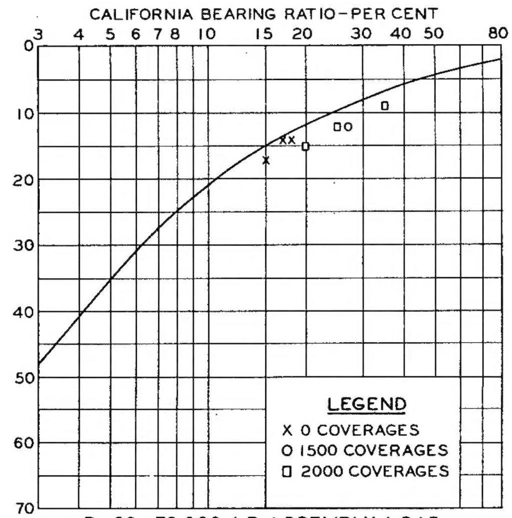
UNITS 4, 5, AND 6 — B-29 LANE

071052-W



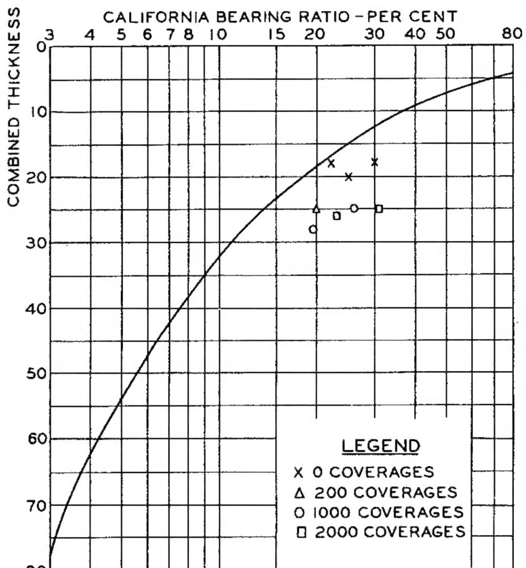
B-36 150,000-LB ASSEMBLY LOAD
140-PSI TIRE PRESSURE

UNITS 1, 2, AND 3



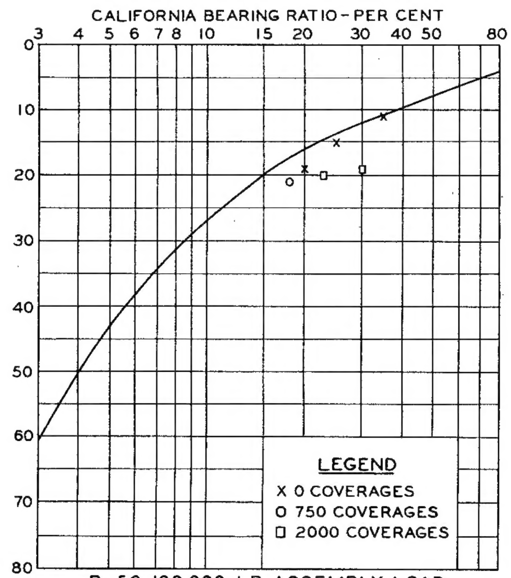
B-29 70,000-LB ASSEMBLY LOAD
100-PSI TIRE PRESSURE

UNITS 4, 5, AND 6



B-36 200,000-LB ASSEMBLY LOAD
198-PSI TIRE PRESSURE

UNITS 1, 2, AND 3



B-50 100,000-LB ASSEMBLY LOAD
190-PSI TIRE PRESSURE

UNITS 4, 5, AND 6

NOTE: CURVES ARE PRESENT DESIGN CURVES FOR THE LOADING INDICATED.
POINTS INDICATE THICKNESS REQUIRED FOR EQUIVALENT SINGLE WHEEL LOAD, COMPUTED BY EQUATING DEFLECTIONS BENEATH SINGLE AND MULTIPLE LOADS.

DESIGN THICKNESSES BASED ON EQUIVALENT SINGLE WHEEL LOADS

071052-X